# MATERIALS HANDBOOK

# MATERIALS HANDBOOK

An Encyclopedia
for Purchasing Agents, Engineers, Executives,
and Foremen

*By* GEORGE S. BRADY

FOURTH EDITION
SECOND IMPRESSION

McGRAW-HILL BOOK COMPANY, INC.
NEW YORK AND LONDON
1940

PRINTED IN THE UNITED STATES OF AMERICA



THE MAPLE PRESS COMPANY, YORK, PA.

## PREFACE TO THE FOURTH EDITION

The First Edition of "Materials Handbook" was published in 1928. It grew out of the author's need for a quick reference to basic data on all kinds of industrial materials when he was American Trade Commissioner to three foreign countries. It began with an intensive study of the materials of each industry and a card index of comparative data.

Accumulated data were based on the ready-reference information needed in preliminary discussions of purchasing requirements. Later, when the author was managing editor of two industrial trade papers, the collection and classification of data were extended to cover the primary requirements of industrial executives, designers, architects, and builders of mechanical equipment and plant.

"Materials Handbook" (Fourth Edition) represents twenty years of work, brought up to date by continuous contact with producers of the materials and by analysis of the current published researches of technical experts in the various industries.

It is not the author's intention to provide an exhaustive treatise on any material, as it is assumed that purchasers and designers will contact producers of the materials for detailed specifications. General information, with the most commonly used comparative figures, is given on materials in their group classifications in order to give a general picture; patented and trade-named materials are then described to give a more specific understanding of commercial applications. The relative position and the length of description of proprietary materials are for purposes of illustration and bear no relation to the relative merits of the products of any one producer. General information on the chief ores and industrial chemicals has been included for more intelligent judgment of the commercial industrial materials.

Statements regarding characteristics of the materials and nomenclature are not the personal opinions of the author, but

are backed by the most competent authorities in each case. Because of the numerous sources of information, it is clearly impossible to give in the published volume credit to the producers and experts who have furnished data, but acknowledgment is here made, in the name of industrial science, to the ready and willing cooperation that has been received from producers, technical authorities, industrial-paper editors, and government bureaus in this country and in England.

GEORGE STUART BRADY.

WASHINGTON, D. C.,
*October*, 1940.

## A FOREWORD FOR THE USER

For the purchasing executive or the product engineer who must think in terms of a very wide variety of materials, nothing is more useful than to fix in the mind a few figures that will serve as milestones to give a quick comparative judgment of material characteristics. A new figure is of little value unless it brings to the mind a comparison with a known value.

Only a few such values need be remembered. For comparison purposes it is well to keep in mind such data as these: The average tensile strength of common low-carbon soft steel is 40,000 lb. per sq. in.; the average point of hardness at which metals are no longer machinable with ordinary tools is 300 Brinell; the average weight of ordinary steel is 7.8 times that of water, and aluminum is about one-third the weight of steel.

A relatively short amount of reading with a perceptive mind will soon fix in the consciousness important points of relativity on strengths, hardness, weights, degrees of screen fineness, of organic compositions, and other matters that will make the path easier for a ready judgment of any new material that may come to the attention.

# MATERIALS HANDBOOK

**Abrasives.** A group of substances used in industry for surfacing and finishing metals, stone, wood, glass, and other materials. The natural abrasives include the diamond, emery, corundum, sand, crushed garnet and quartz, tripoli, and pumice. The artificial abrasives are marketed under many trade names, but are in general either silicon carbide or aluminum oxide.

For industrial grinding, artificial abrasives are preferred to natural abrasives because of their greater uniformity. Grading is important because uniform grinding requires grains of the same size. The abrasive grains are used as a grinding powder, or are made into wheels, into blocks or "stones," or are bonded to paper or cloth. The crushed material is graded in sizes from 8 to 240 and marketed in kegs or cans. Coarse grain is 12 to 24 grit, and very fine is 150 to 240. Floated flours consist of grains of extreme fineness and uniformity marketed as Grinding flour for grinding optical glass and fine cutlery. Grinding flour grains are sizes from 280 to 600 mesh. The massive natural abrasives, such as sandstone, are often cut into wheels from the block. See Grindstones.

The hardest abrasive is the diamond, having a hardness of 10 on the Moh scale. The artificial abrasives silicon carbide and boron carbide have a hardness above 9. Garnet is one of the softest of the so-called hard abrasives, with a hardness of 6 to 7.5. Rouge is one of the hardest of the soft abrasives, with a hardness of 5.5 to 6.5. The "mild" abrasives, used in silver polishes and window-cleaning compounds, such as chalk and talc, have a hardness of 1 to 2 Moh. Abrasives for metal polishes may also be pumice, diatomite, silica flour, tripoli, whiting, putty powder, china clay, tin oxide, or fuller's earth. This type of fine abrasive must be of very uniform grain in order to prevent scratching. Ground glass, or Powdered glass, is regularly marketed as an abrasive. See also Buffing compositions.

In the metalworking industry, aluminum oxide wheels are used for grinding materials of high tensile strength. Silicon carbide is harder, but is not as strong as aluminum oxide, and it is used for grinding metals that have dense grain structure, and for stone and tungsten carbide. See Aluminum oxide and Silicon carbide.

There are five processes for making Abrasive wheels, each giving different characteristics: Vitrified wheels are made by running the mixture into molds, and when dry subjecting to intense heat. They are used for heavy work up to 6,500 surface ft. per min. The silicate process consists in tamping the material into molds with a silicate binder, and then baking in an oven. The silicate bond releases the grains easier than the vitrified. Synthetic resins, such as the phenol resins, are used for bonding where greater strength is required than is obtained with the silicate, but less openness than with the vitrified. Resinoid bonds are used up to 9,500 surface ft. per min., but cut-off wheels are operated far beyond this point. A binder of shellac is used on wheels for light work and for finishing. Rubber is used for high speed or fine finish.

The choice of a binder for grinding wheels is important, as it must be strong enough to hold the grains together to accomplish the desired results, and then to release them before they become too dull. Coarse-grained wheels are used for fast removal of stock or for ductile materials, and fine-grained for hard and brittle material or for fine finish. With any given bond the amount of bond determines a hard or soft wheel as distinct from hard or soft grains. The structure, or spacing of the grains in the bond, must be uniform to obtain uniform grinding.

**Abrasive garnet.** Garnet is the general name of a group of minerals varying in color, hardness, toughness, and method of fracture, used for coating abrasive paper and cloth and for cutting glass and stone. Almandite is the type most used for abrasive purposes, although andradite and rhodolite are also employed. The best garnet abrasives come from the red almandite obtained in large crystals in New York state. The garnet of

North Carolina is a by-product of kyanite mining. The ore contains 10 per cent garnet, 15 kyanite, and 30 mica.

Garnet-coated paper and cloth are preferred to quartz for the woodworking industries, because garnet is harder and gives sharper cutting edges, but artificial aluminum oxide is now often substituted for garnet. The less expensive quartz may also be used, and is sometimes colored to imitate garnet. The grades of garnet grains used on Garnet paper and cloth range from No. 5, the coarsest, which is about 15 mesh, to 7/0, the finest, which is about 220 mesh. The paper used as a backing is a good quality of kraft paper of 50 or 70 lb. weight, or a rope manila stock of various weights. The usual size is 9 by 11 in. The cloth is usually in two weights, the light weight being used as a flexible rubbing-down material.

Some garnet is made into wheels by the silicate or shellac processes, but vitrified wheels are not made because of the low melting point of garnet, 1300°C. Garnet from the mines is crushed, ground, and separated, and graded in settling tanks and silk sieves. Hornblende is a common impurity and is difficult to separate, but good quality abrasive garnet should be free of this mineral. See Almandite, Andradite, and Rhodolite.

**Abrasive sand.** Any kind of natural sand used for abrasive and grinding purposes, but the term does not include the sharp grains obtained by crushing quartz and used for sandpaper. The chief types of abrasive sand include sandblast sand, glass-grinding sand, and stone-cutting sand. Sand for stone sawing and for marble and glass grinding is usually ungraded, with no preparation other than screening, but it must have tough, uniform grains. Chats is a name for hard sand tailings from the Missouri lead ores, used for sawing stone. Banding sand is used for the band grinding of tool handles, and for the grinding of plate glass, but it is often replaced by artificial abrasives. Banding sand grains are fine, 95 per cent being retained on a 150-mesh screen. Burnishing sand, used for metal polishing or grinding valve seats, is a fine-grained, clean silica sand with rounded grains. It should pass a 65-mesh screen, and be retained on a 100-mesh screen. See Sand, Sandpaper, Scouring abrasive.

**Acaroid resin.** A natural resin obtained from various species of the tree *Xanthorrhoea* of Australia and Tasmania, and used in paints and varnishes, in paper sizing, and in waxes. It is also called Gum acroides. The Yellow acaroid, mostly from the X. *preissii* of Western Australia, comes in small hollow pieces of yellow to reddish color. It is known as Black boy resin, the name coming from the appearance of the tree. Red acaroid, known also as Red gum and Grass tree gum, comes in small dusty pieces of reddish-brown color. This variety comes from various species of the tree. The resins contain a high percentage of tannols. They are soluble in alcohols and aniline, only slightly soluble in chlorinated compounds, and insoluble in coal-tar hydrocarbons. Acaroid has some of the physical characteristics of shellac, but darkens on aging.

**Acetaldehyde.** A water-white inflammable liquid with an aromatic penetrating odor, used in the manufacture of synthetic resins, in rubber antioxidants, as a preservative, for making dyestuffs, and for silvering mirrors. It has the composition $CH_3 \cdot CHO$, is a reducing agent, and forms acetic acid on oxidation. The specific gravity is 0.801 and boiling point 20.8°C. It is soluble in water, in alcohol, and in naphtha. Acetaldehyde is made by the oxidation of ethyl alcohol. Paraldehyde, $(CH_3 \cdot CHO)_3$, which is often used instead of acetaldehyde in resin manufacture, has a higher boiling point, 100 to 127°C., is less flammable with higher flash point, but is not as reactive and will not reduce silver solutions to form a mirror. It is used in the tanning industry for fulling leather.

**Acetamide.** Also called Acetic acid amine. A grayish-white crystalline solid with a melting point of 77 to 81°C., specific gravity 1.139, composition $CH_3 \cdot CO \cdot NH_2$, and slight mousy odor. It is soluble in water and in alcohol, and the solution has remarkable solvent properties. It is also used as a liquid flux for soldering on painted or oily surfaces. Its ability to dissolve starch and dextrine makes it valuable for adhesives for waxy papers. It is also used as an antacid in lacquers and in explosives, as a softening agent in glues and leather coatings, and as a non-hazing plasticizer in cellulose nitrate and acetate films. With

added corrosion inhibitors it is used as an antifreeze mixture in radiators, a 50 per cent solution in water having a freezing point of −27.5°C. Acetaldehyde ammonia, $CH_3{\cdot}CHOH{\cdot}NH_2$, is a white crystalline solid with melting point of 80°C. It is used as a vulcanization accelerator in rubber, as a pickling inhibitor for steel, and in the manufacture of plastics. Aldamine is the trade name of the Niacet Chemicals Corporation for this latter product.

**Acetic acid.** An organic acid of the composition $CH_3{\cdot}COOH$, having a wide variety of industrial uses. It is employed as a weak acid for etching and for soldering, in stain removers and bleaches, as a preservative, as a solvent for essential oils, resins, and gums, as a precipitant for latex, and in tanning leather. It is a highly corrosive liquid with a pungent odor. The specific gravity is 1.049, boiling point 118°C., and it becomes a colorless solid below a temperature of 16.6°C. The pure solid is known as Glacial acetic acid. Standard and Laundry special contains 99.5 per cent of acid. Water is the chief impurity. The acid occurs in citrous fruits and vegetables, but commercially it is produced as one of the products in the destructive distillation of wood. Acetic anhydride, a colorless liquid of the composition $CH_3COOCOCH_3$, and boiling point 139.5°C., is a more powerful acetylating agent, and is used in making cellulose acetate, rayon, and photographic film. It forms acetic acid when water is added.

**Acetone.** An important industrial solvent, used in the manufacture of lacquers, celluloid, smokeless powder, for dewaxing lubricating oils, for dissolving acetylene for storage, and as a raw product in the manufacture of other chemicals. It is a colorless, inflammable liquid with a mintlike odor. The composition is $CH_3{\cdot}CO{\cdot}CH_3$, specific gravity 0.790, boiling point 56°C., and solidification point −94°C. Acetone is prepared by a special fermentation of grain, forming butyl alcohol and acetone. The oily residue from the distillation of acetone is called Acetone oil, and is used as a denaturant of alcohol.

**Acetylene.** A colorless gas of the composition $CH{\cdot}CH$, used in the mechanical industries for welding torches and for lighting.

It contains 92.3 per cent of carbon, and is therefore nearly gaseous carbon. When pure, it has a sweet odor, but has a disagreeable odor when it contains hydrogen sulphide as an impurity. Acetylene burns brightly in the air, and when mixed with oxygen as Oxyacetylene for welding, it gives a temperature of 3500°C. In a mixture of about 3 per cent acetylene to 97 of air, it is used as an explosive gas. The maximum explosive effect is with a mixture of 7.7 per cent of the gas with 92.3 of air. The gas has a specific gravity of 0.92. It is nontoxic, and is soluble in water, alcohol, or in acetone. It liquefies under a pressure of 700 lb. per sq. in. at 70°F. Acetylene is easily generated by the action of water on calcium carbide. It is marketed compressed in cylinders dissolved in acetone to make it nonexplosive. One volume of acetone will dissolve 25 volumes of acetylene at atmospheric pressure, or 250 volumes at 10 atm. Prestolite is a trade name of the Prestolite Company, Inc., for acetylene dissolved in acetone.

**Acrylic resins.** Colorless, transparent synthetic resins prepared by the polymerization of acrylic derivatives, chiefly from the esters of Acrylic acid, $CH_2{:}CH{\cdot}COOH$, and Methacrylic acid, $CH_2{\cdot}C(CH_3){:}COOH$. They vary from soft, sticky semiliquids to hard, tough thermoplastics, and are used for adhesives, protective coatings, leather finishes, laminated glass, and molded products. Acrylic resins are stable, and are resistant to chemical action. They do not cloud or fade in light when used as a laminating material in glass. For molding they are compounded with talc, carbon black, and other fillers and pigments the same as other synthetic resins. Methyl methacrylate is a hard rigid resin of the acrylic series. The density is 1.19, tensile strength 9,000 lb. per sq. in., refractive index 1.49, Brinell hardness 17 to 20, and it is superior to glass in the transmission of ultraviolet light. The direct transmission of white light is 93 per cent. It has high dielectric strength, is resistant to salt and acid solutions, and is stable to light. It is valued as a material for windshield glass, and for molded or cast products where transparency is desired. It softens at 190 to 240°F., for molding thermoplastically. Lucite is the trade

name of a methyl methacrylic resin of E. I. du Pont de Nemours & Company, Inc. Plexiglas is the cast resin in sheets $\frac{1}{16}$ to $2\frac{1}{2}$ in. thick used for windows in aircraft. Acryloid is the name of the acrylic ester resins of the Resinous Products & Chemical Company, Inc., used for coatings which require strong adhesion. Vernonite and Lucitone are also trade names for acrylic resins. Crystalite, of the Röhm & Haas Company, Inc., is an acrylic molding powder.

**Activated charcoal.** A charcoal made by heating anthracite, coconut shells, peach pits, or other organic substances to drive off all traces of hydrocarbons and treating to obtain chemically active charcoal. It is used as an absorbent material for gas masks, and for purifying acids, recovering solvents, and decolorizing liquids. Coconut charcoal is an activated charcoal made by heating coconut shells in a closed retort, crushing, and steam treating. Norit and Dorsite are trade names for this charcoal. Activated charcoal from anthracite is called Bachite. Kelpchar, used for decolorizing, is made from seaweed. Activated charcoals are also made by various chemical processes. A requirement of these charcoals, besides great absorbing power, is that they possess strength to retain a porous structure to pass the air or liquid. See Charcoal.

**Adhesives.** Materials, usually solutions in liquid form, employed for sticking, or adhering, one surface to another. The usual commercial adhesives include pastes, glues, lutes, pyroxylin cements, rubber cements, latex cement, and special synthetic cements of Neoprene, Pliolite, or other proprietary material. Adhesives are characterized by the degree of tack, or stickiness, by their strength of bond after setting or drying, by the rapidity of bonding, and by their durability. The tack is frequently increased by adding rosin or ester gum, while the speed of drying may be altered by changing the solvent. The strength of bond is inherent in the character of the adhesive itself, particularly in its ability to adhere intimately to the surface to be bonded. Since most adhesives are prepared from organic products, they are subject to rapid disintegration on exposure, and the life of the adhesive depends usually upon the stability of the particular

ingredient which gives the holding power, although otherwise good cements of synthetic materials may disintegrate by the oxidation of fillers or materials used to increase tack.

Pastes, in general, are water solutions of starches or dextrines, usually mixed with gums, resins, or glue. They are the cheapest of the adhesives, but deteriorate rapidly on exposure. They are mostly employed for the adhesion of paper and paperboard. More expensive Latex pastes, of the rub-off type, are used for such purposes as photographic mounting. Glues are usually water solutions of animal tissues, and are stronger and more durable than pastes. See Glue. Mucilages are light vegetable glues. See Mucilage. Pyroxylin cements may be merely solutions of nitrocellulose with chemical solvents, or they may be compounded with resins, or plasticized with gums or synthetic resins. They dry by the evaporation of the solvent, and because of their ability to adhere to almost any type of surface, are called Household cements. Cellulose acetate may also be used. These cements are used in the shoe industry for bonding the soles of women's shoes. The bonding strength is about 20 lb. per sq. in., or equivalent to the adhesive strength of the outer fibers of the leather to be bonded. Cold solder is pyroxylin cement mixed with aluminum powder to give a metallic appearance.

Rubber cements for paper bonding and photograph mounting are simple solutions of rubber in a chemical solvent, and, like the latex pastes, the excess can be rubbed off the paper. Stronger rubber cements are usually compounded with resins, gums, or synthetics. Rosin may be added to increase tack. An infinite variety of these cements is possible, and they are all waterproof with good initial bond, but they are subject to rapid deterioration on exposure. Curing cements are rubber compounds to be cured by heat and pressure or by chemical curing agents. They are stronger, give better adhesion to metal surfaces, and have longer life. Latex cements are water solutions of rubber latex. They provide excellent initial tack, and give strong bonds to paper, leather, and fabric, but they are subject to rapid deterioration unless cured.

Cements compounded from synthetic products are less subject to deterioration than the vegetable and animal products,

and may have high bonding strength. They are the only adhesives that give reliable cold bonds to metals, especially after curing or chemical setting. Cold bonds as high as 300 lb. per sq. in. can be obtained with compounded synthetic cements, while heat-cured bonds as high as 1,000 lb. per sq. in. can be obtained. Neoprene cements may be simple solutions of Neoprene in a solvent with strengthening fillers and a curing agent, or they may be compounded with resins. Like the self-curing rubber cements, they are usually marketed in two parts, and are cured by aging or by heat and pressure.

**Admiralty metal.** Also erroneously called Admiralty bronze. An alloy containing about 70 per cent of copper, about 1 per cent of tin, and the remainder zinc. The usual alloy is a 70–30 cartridge brass with 1 per cent of the zinc replaced with an equal amount of tin. This composition is listed by the American Brass Company as Admiralty alloy. The tin increases the hardness and strength, but decreases the ductility. United States government specifications permit up to 0.06 per cent of iron and 0.075 lead as impurities. The alloy has been standard for condenser tubes, and where corrosion resistance is required, but aluminum brass now frequently replaces it. See Ambraloy. The weight is 0.305 lb. per cu. in. It machines readily, especially when it contains lead. See Naval brass.

**Agar-agar.** A gelatinous substance obtained from various species of seaweed, *Algae*, mostly from the Pacific and Indian Oceans. When dissolved in water it forms a transparent jelly, and its chief industrial applications are in making gums and resins for molding. It is also used commercially for fixing bacteria for counts, in toilet lotions and medicines, and in foods. Kanten is a variety of agar-agar from the red Tengusa seaweed, *Gelidium corneum*, of Japan. Commercial agar-agar is colorless, yellowish, or pink to black. It is marketed in strips, blocks, or shredded, and is obtained by boiling the dry seaweed and straining out the insoluble matter.

Algin, or Alginic acid, is obtained from seaweeds as a by-product in the manufacture of iodine and potash, and is used in the manufacture of molding compounds. It is a colorless

mass resembling gelatine, and has the empirical formula $C_{21}$-$H_{27}O_{20}$. When dry it becomes hard and horny, insoluble in alcohol, and only slightly soluble in water. But Sodium alginate, made by dissolving in a sodium carbonate solution and neutralizing with hydrochloric acid, forms tough, flexible, colorless sheets, soluble in water. When applied as a coating for fabrics, the sodium alginate is again treated with acids to make it insoluble and waterproof.

**Agate.** A natural mixture of crystalline and colloidal silica, but consisting mainly of the mineral chalcedony. The siliceous material usually occurs in irregular banded layers of various colors. The stone is used for knife-edges and bearings of instruments, and for pestles and mortars. It is also made into ornamental articles, and the finer specimens are employed as gem stones. Agate was formed by the deposition of vapor in eruptive rocks, and consists of about 98 per cent silica, colored with metallic oxides. The largest and finest agates come from Uruguay and Brazil, but the center of agate working is in Germany. Moss agate encloses filaments, mostly green, suggestive of moss. The moss agates of Montana are used as gem stones. Commercial agates may be artificially stained with mineral oxides and salts, or treated with acids to bring out color differences.

**Aich's metal.** An old name for a brass containing iron. The iron content may be as high as 3 per cent, but a typical composition is 60 per cent of copper, 38.2 zinc, and 1.8 iron. It is about the same composition as an early brass known as Gedge's metal, and a similar alloy was also called Sterro metal. The alloy is harder than ordinary brass, has a golden-yellow color, and resists oxidation. Iron-bearing brasses are now employed for such uses as hydraulic cylinders and for forgings. See Delta metal and Muntz metal.

**Aircraft metals.** Alloy steels are now extensively used for structural members because their superior strength permits smaller cross sections to obtain greater strength than is obtained with aluminum alloys. Chrome-vanadium steel and chrome-molybdenum steel are the most commonly employed. Federal

specifications for chrome-molybdenum seamless tubing call for 0.80 to 1.10 per cent of chromium, 0.15 to 0.25 molybdenum, and 0.25 to 0.35 carbon. The tensile strength exceeds 95,000 lb. per sq. in. A steel for wing struts contains 0.25 to 0.35 per cent of carbon, 2.5 to 3.5 nickel, 0.80 chromium, and 0.35 molybdenum. The tensile strength is 180,000 lb. per sq. in., and elongation 12 per cent. S.A.E. 3115 and S.A.E. 3135 nickel-chromium steels are furnished by the mills in aircraft quality hot-rolled bars. Stainless iron and steels are also used. Cast iron and cast steel have only limited use for aircraft because the strength-weight factors are low, but because of good wearing qualities and ability to cast in thin sections high-test cast iron may be used for cylinders. An iron in one engine has 3.1 per cent total carbon, 2.1 silicon, 1.50 nickel, 0.30 chromium, and 0.50 molybdenum. The tensile strength is 50,000 lb. per sq. in., and hardness 240 Brinell. Copper-silicon steel, containing 1.50 to 2.0 per cent copper, 1.0 to 1.25 silicon, 1.10 to 1.35 manganese, and 0.12 to 0.20 carbon, is used for castings for landing-gear assemblies. It has high fluidity, and can be run in thin sections.

Aluminum alloys are used for some members, sheets, forged parts, and castings. Duralumin and 17S are the most widely employed. Magnesium alloys are used for engine pistons and bulky parts. Y-alloy is used for cylinder jackets and pistons. A magnesium alloy containing 7 per cent of aluminum and 0.40 manganese has been used for engine parts. Aluminum bronzes are employed for bearings, and silicon steels for valves. A nickel silver in strip and sheet form used by the British Air Ministry contains 45 per cent nickel, 23 zinc, and 32 copper. In hard-rolled sheet it has a tensile strength of 60 tons per sq. in. Stainless steel is valued for sheeting, structural members, and rivets, because of its resistance to corrosion, ease of welding, nonmagnetic properties, and shock resistance at low temperatures. Ribs of stainless steel are cold-worked to a tensile strength of 175,000 lb. per sq. in. Sheet stainless steel for wing covering for army planes is cold-worked to 185,000 lb. per sq. in.

Vital parts of high-grade engines, such as crankshafts and connecting rods, are of heat-treated nickel-chromium steels,

or S.A.E. steel X4340. This steel, which contains 1.5 to 2.0 per cent of nickel, 0.60 to 0.90 chromium, and 0.20 to 0.30 molybdenum, can be machined up to 450 Brinell, and has a tensile strength of 230,000 lb. per sq. in., with elongation of 12 per cent.

**Alcohol.** The common name for ethyl alcohol, but the term properly applies to a large group of organic substances which have important uses in industry, especially as solvents and in the preparation of other materials. See Ethyl alcohol, Methyl alcohol. A characteristic of the primary alcohols is that there is always a $CH_2OH$ group in the molecule. The secondary alcohols have a CHOH group, and the tertiary alcohols have a distinctive COH group. Alcohols with one OH group are called monohydroxy, and those with more than one OH group are known as Poly-hydroxy alcohols. Another method of classification is by the terms saturated and unsaturated. The alcohols vary in consistency. Methyl alcohol is like water, amyl alcohol is oily, and messyl alcohol is a solid. The common alcohols used in industry are ethyl, methyl, amyl, and butyl. The high alcohol, Octyl alcohol, is used as a defoaming agent in varnish and rubber latex, and as a wetting agent for pigments. It is a colorless liquid with a boiling point of 183.5°C., only slightly soluble in water. The composition is $C_4H_9CH(C_2H_5)CH_2OH$. See also Amyl alcohol and Poly vinyl alcohol.

Many of the alcohols are made easiest by fermentation; others are produced from hydrocarbons. Much of the American production of ethyl alcohol is from sugar, chiefly from Blackstrap molasses, which is a by-product of the cane sugar industry and contains 50 to 60 per cent of sugar, mostly sucrose, but also some glucose. Ethyl alcohol made from starch is more expensive and is limited to Beverage alcohol. Synthetic alcohol is made by various processes, but the most important source is the natural gases from the cracking of petroleum by the ethylene-sulphuric acid reaction. Solidified alcohol is a name applied to a jellylike solution of nitrocellulose in ethyl alcohol, marketed in tins and used in heaters and small stoves. It burns with a hot flame without exploding.

**Aldehyde.** A group name for substances made by the dehydrogenation or oxidation of alcohols, such as formaldehyde from methyl alcohol. By oxidation again the aldehydes form corresponding acids, as formic acid. The aldehydes have many industrial uses, among which are the manufacture of synthetic resins and disinfectants. Aldehydes occur in animal tissues and in the odorous parts of plants, giving flavor and odor to many of these. The aldehydes have the radical group, CHO, and because of their ease of oxidation are important reducing agents. See Formaldehyde, Acetaldehyde, Furfural.

**Alder.** The wood of the tree *Alnus glutinosa*, which belongs to the beech family and is widely distributed in the northern hemisphere. The wood is tough and resilient, and is valued as a plywood, and for cabinet work and toy manufacture. It is of a reddish-white color, and has a smooth, fine grain, with a weight of about 35 lb. per cu. ft. Red alder is from the *Alnus oregona*, a large tree of North America. Formosan alder is from the tree *Alnus maritima* of Asia. The wood is light yellow streaked with reddish lines and has a fine texture.

**Aldol.** A thick, viscous, pale-yellow liquid of the composition $CH_3{\cdot}CHOH{\cdot}CH_2{\cdot}CHO$, known also as Acetaldol. It is employed to replace formaldehyde in the manufacture of synthetic resins, as an ingredient in cadmium plating baths, in dye baths, in refining ores, and in the manufacture of butadiene rubber. It has a specific gravity of 1.090 to 1.105, and is soluble in water and in alcohol. The purest form is Paraldol, which is a double molecule of aldol, and is a white crystalline product with a melting point of about 97°C.

**Alkali.** A caustic hydroxide characterized by its ability to form soluble soaps with fatty acids. The common alkalies are sodium hydroxide and potassium hydroxide, and these are the ones used in soluble oils and cutting compounds, in soaps and cleaning solutions, and for etching aluminum alloys. See Sodium hydroxide. All of the alkalies have a brackish taste and a soapy feel, and most of them corrode animal and vegetable tissues, from which characteristic they derive the names caustic

potash and caustic soda. The Alkali metals are sodium, potassium, lithium, caesium, and rubidium, as these have a basic reaction in their hydroxides and carbonates. The carbonates of the alkaline metals are called Fixed alkalies. Thin films of the alkali metals are transparent to ultraviolet light but opaque to visible light, and are used to filter light. The hydroxides of calcium, strontium, and barium show a strong alkaline reaction in solution, and are called the Earth metals. Ammonia is called a Volatile alkali.

**Alkyd resins.** A group of synthetic resins known chemically as hydroxy-carboxylic resins, of which the one produced from phthalic anhydride and glycerol is representative. Phthalic anhydride is a white, crystalline product of the composition $C_6H_4(CO)_2O$, and melting point of 126°C. The alkyd resins have characteristics that make them especially suitable for varnishes and enamels. For such use they are modified with drying oils, and find use as finishes for automobiles, and in white refrigerator enamels and marine finishes. They bake to a high gloss, and are resistant to oils, light, and weathering. The oil-modified resins are also used as waterproof coatings for silk and other fabrics. Amberlac and Duraplex are alkyd lacquers of the Resinous Products & Chemical Company, Inc. Other alkyd resins are Beckol, of Beck, Koller & Company, Inc., Dulax, of E. I. du Pont de Nemours & Company, Inc., and Teglac, of the American Cyanamid Company. Petrex resin is the name of a series of alkyd resins of the Hercules Powder Company used in lacquers, varnishes, adhesives, and inks. Glyptal, of the General Electric Company, is a phthalic anhydride-glycerin resin for molding and for lacquers and insulation. The resins have high adhesion to metals, and are tough, flexible, and durable. In lacquers they have high gloss, and as insulating coatings they withstand elevated temperatures and are resistant to oils.

**Alligator leather.** A light, tough leather with platelike scales on the surface. It is made from the skins of large saurians, or lizards of the order *Crocodilia*, abounding in muddy tropical streams. The species *Alligator mississippiensis* inhabits the

swamps of Southeastern United States. The mature animal is usually about 7 ft. long, and reaches this length in little over 5 years. Alligator leather was first used in commercial quantities in 1855, and is now especially valued for pocketbook, bag, and shoe leathers. It is much imitated with embossed split sheepskins. Lizard leather, from the Java ring lizard, is another reptile leather valued for women's shoes.

**Alloy.** A solid solution of two or more metals. Chemically, an alloy is a solution that is entirely homogeneous, but the commercial use of the term also includes mixtures of metals that do not dissolve in each other. Lead, for example, does not dissolve in copper but forms separate particles in the metal matrix. Lead does not dissolve in steel but forms strings in the metal. Nevertheless, both combinations are useful and are called alloys. The commercial utility of an alloy arises from the fact that the pure metals are often too soft, weak, or rare for use alone. Thus, copper, a soft metal, when alloyed with the brittle metal zinc, forms a strong, hard alloy, brass, that has many commercial uses.

Studies of alloys show definite relations which one metal bears to another, and definite characteristics which can be obtained from the combinations, although these are also changed by the interaction which one alloying element may have on another. Thus, silicon and nickel give definite added properties to copper when added separately, but give an additional separate property when used together because of the formation of a nickel-silicide compound. Some alloys contain chemical crystals of the metals. Thus, bronze contains a percentage of copper-tin crystals; in brass the copper and zinc may be mechanically dissolved. The melting point is always lowered by the addition of one metal to another. The number of possible alloys is infinite. They are made by the fusion of the metals, as distinct from products made by the diffusion of particles in close contact. See Widia metal. The most common general groups of alloys are: brass, bronze, babbitt, alloy steels, nickel silver, aluminum alloy. A Technic alloy is a low-cost alloy used in laboratories or dental schools to avoid the use of expensive alloys of gold

or platinum in practice working. They are usually copper or aluminum base, with tin, nickel, silver, and iron, to give the approximate working characteristics of the expensive metal. A Master alloy, or Foundry alloy, is an alloy used for adding elements to metals in the foundry.

**Alloy steel.** A general name for steels which owe their distinctive properties to elements other than carbon. Alloy steels usually take the name of the element or elements having the greatest influence on the characteristics of the alloy, regardless of the percentage of the element contained in the steel. These alloy steels include vanadium steel, nickel steel, nickel-chromium steel, tungsten steel, manganese steel, and silicon steel. High-speed steels are usually classed as a separate group. The American Iron & Steel Institute defines alloy steel as a steel in which a minimum limit is specified or guaranteed for alloying elements. These minimum percentages are: chromium, 0.25; copper, 0.60; manganese, 1.65; molybdenum, 0.05; nickel, 0.25; silicon, 0.50; or any amounts of titanium, tungsten, or molybdenum. Steels having casual amounts of these elements less than those specified are therefore not officially rated as alloy steels, although vanadium steel may be any carbon steel that has been cleansed with vanadium. Alloy steels are also marketed under a great variety of trade names, covering a particular steel, such as Tufaloy, a high-strength cast steel of the Fort Pitt Steel Casting Company, or covering a wide range of steels, such as Agathon steel, of the Central Alloy Steel Corporation, and Carilloy, of the Carnegie-Illinois Steel Corporation.

The alloy steels are used for automotive and machinery parts where high strength or special properties such as abrasive resistance are required. Most tool steels are now alloy steels. See also Heat-resistant alloys, Stainless steels. Universal steel is a name applied to alloy steels containing a low percentage of carbon to give them a wide range of utility. They are generally nickel-chromium steels, as these can be used with carbon as low as 0.15 per cent without losing their heat-treatment properties. High-alloy steels are steels containing very large percentages of elements other than iron, usually to obtain some

special property, such as corrosion resistance, and they are often not steel in the true sense, but are iron alloys.

**Almandite.** A variety of garnet, produced chiefly in New York state, and used as a coating for abrasive paper and cloth. The composition of pure almandite is $Fe_3Al_2(SiO_4)_3$. It forms crystals of a fine deep-red color, with a hardness of about 7.5 Moh. Precious garnets, used as gem stones, are choice specimens of almandite, found in India and Brazil. See Abrasive garnet.

**Alpaca.** An English white alloy employed as a base metal in tableware. It contains about 65 per cent of copper, 20 zinc, 13 nickel, and 2 silver. Its color is quite similar to that of silver. It is usually plated with silver, takes a fine polish, and is resistant to corrosion. Alpaca is widely imitated, often without the silver. See Nickel silver.

Alpaca is also the name of a fabric made from Alpaca fiber, the fine wool-like hair of animals of the llama family of Bolivia, Peru, Chile, and Argentina. Alpaca fiber is long and fine, with a downy feel, but it does not have the strength or elasticity of wool. Llama hair, from the llama of Bolivia, is marketed as Coarse alpaca. The Vicuña, another animal of the llama family, is almost extinct, and the commercial Vicuña cloth is made of alpaca or fine wool, or mixtures. Alpaca and Vicuña cloth are used for shawls, jackets, and fine goods.

**Alum.** A colorless to white crystalline substance of the composition $K_2SO_4 \cdot Al_2O_3(SO_3)_3 \cdot 24H_2O$, occurring naturally as the mineral Kalinite, and also in combination as the mineral Alunite. It has a sweetish taste and is very astringent. It is used as an astringent in the leather and textile industries, for purifying water, and in pigments. From a water solution it crystallizes out, taking with it the organic impurities, thus giving a high purifying value. Alum has a specific gravity of 1.757, melts in its water of crystallization at 93°C., and when heated to redness is converted into Burnt alum, a porous, friable material which dissolves slowly in water. Alumstone is a gray or pinkish massive form of alunite found in volcanic rocks. A pure variety from Italy is called Roman alum, or Roche alum. Soda alum,

in which the potassium is replaced by sodium, occurs naturally in the South American Andes as the mineral Mendozite. It is more soluble than alum, but is more difficult to purify. Filter alum, also called Patent alum and Aluminous cake, used for water-works filtration, is Aluminum sulphate, $Al_2(SO_4)_3$, plus a varying amount of water in chemical combination. It is a white crystalline solid readily soluble in water. When Filter alum contains a slight excess of alumina it is called basic. Commercial aluminum sulphate is also called Concentrated alum, and now replaces Potash alum for many uses because of its cheapness. For use in pickling and tanning leather it contains not more than 0.01 per cent of iron oxide. Ammonia alum, used in tanning sheepskins and fur skins, is Ammonium-aluminum sulphate, a combination of aluminum sulphate and Ammonium sulphate, $(NH_4)_2SO_4$, containing about 37 per cent of the former and 14 of the latter, with the remainder water of crystallization. It is also valued for water purification because it forms chloramine.

**Alumina.** The oxide of aluminum, $Al_2O_3$. In natural crystalline form it is used as an abrasive and for gem stones. It is also widely distributed in combination with silica and other minerals. See Corundum, Bauxite, Aluminum oxide. It is an important constituent of the clays for making porcelain, bricks, pottery, and refractories. See Refractories. Pure alumina is a white, amorphous powder when prepared by precipitation and calcining. The melting point is 3670°F. It is also used as a mordant in dyeing. Activated alumina is a partially dehydrated aluminum trihydrate in the form of hard porous masses. It has a strong affinity for moisture or gases and will remove them from the air. Heating will then reactivate the alumina by driving out the gases or moisture. It is also used for dehydrating organic solvents.

**Aluminate cement.** A construction cement made like portland cement but with bauxite as the raw material. It is distinguished by its quick-setting property, reaching a strength in 24 hr. as high as that obtained in ordinary cement in 28 days, and is thus valuable for laying roads or bank walls. Aluminate cement contains about 40 per cent of alumina, 40 lime, 15 iron

oxides, and 5 silica and magnesia. An intermediate cheaper cement, called Accelerated cement, that will set in about 3 days, is portland cement with a high percentage of lime. Lumnite cement is the trade name of an aluminate cement of the Atlas Lumnite Cement Company.

**Aluminum.** Also called Aluminium in England. A bluish-white metal, symbol Al, obtained chiefly from the mineral bauxite by roasting and reducing. It is the most widely distributed of all the elements next to oxygen and silicon. It occurs in all common rocks, but is difficult to extract. The metal was discovered in 1727, but did not become commercial until it was reduced electrolytically in 1885. Aluminum has a specific gravity of 2.70, and its lightness makes it valuable for transport equipment, about 20 per cent of the entire production being used for this purpose. The metal melts at 1218°F., is resistant to corrosion, but is attacked by alkalies and hydrochloric acid. It is nonmagnetic, even when highly alloyed with iron. However, its physical properties are greatly affected by even slight additions of other elements. The tensile strength of cast aluminum is 12,000 lb. per sq. in., with an elongation of about 30 per cent and a Brinell hardness of 30. Annealed wrought aluminum, 99.9 per cent pure, has a tensile strength of 9,000 lb. per sq. in., and elongation of 60 per cent. The electrical conductivity is 59 per cent that of copper. The coefficient of expansion is 0.0000137. The chief impurities in commercial aluminum are copper, iron, and silicon, but sheet aluminum averages 99.3 per cent pure. Alcoa 2S is commercially pure aluminum of the Aluminum Company of America. Federal specifications for commercial sheet aluminum call for a tensile strength, soft, of 15,500 lb. per sq. in., and hard, 22,000 lb. per sq. in. So great is the effect of alloying elements in aluminum that a commercial aluminum 99.2 per cent pure will have a tensile strength 25 per cent greater than 99.9 per cent pure aluminum but will be harder. Pure aluminum is next to gold in the order of malleability.

Aluminum ingot metal is usually 99 per cent pure. Commercial aluminum comes in three grades: above 99 per cent

aluminum, 98 to 99 per cent, and 94 to 98 per cent. Special grades can be obtained 99.8 per cent pure. The third grade contains zinc and is used as a deoxidizer. Aluminum is employed as a light metal for automotive and airplane construction, for moving parts of machinery, for ornamental architectural work, and for cooking utensils. Much of the material used under the name of aluminum consists of aluminum alloys. The metal is transparent to X rays, and is used in thin sheets as ray filters. Aluminum is marketed in ingots, castings, sheets, rods, and tubes. See Aluminum alloy and Alclad.

Aluminum sheet is finished by cold-rolling in Gray plate and Bright finish, the former being produced by allowing the rolls to take on a coating of fine particles and oxide. Very thin sheets are rolled in packs, and sheets as thin as 0.0005 in. can be rolled. See Aluminum foil. The ¼-in. diameter rod is the smallest produced by rolling. Smaller sizes are classified as wire and are drawn. Wire as small as 0.0025 in. is produced. The 1-lb. notched ingot is the usual form of the metal marketed for die-casting. In powder form aluminum is used for paints and fireworks. See Aluminum powder and Thermit. Aluminum can be surface-colored in many shades by immersion in solutions of ammonium hydroxide containing salts of metals, or can be dyed chemically. Alumilite is the trade name of Aluminum Colors, Inc., for colored chemical coatings applied to aluminum electrolytically.

**Aluminum alloy.** A term which, when not qualified in any other way, refers to Aluminum-copper alloys with or without other alloying elements. Copper hardens and strengthens aluminum, and also gives age-hardening properties, especially when a small amount of magnesium is present. Aluminum alloy also casts easily. In casting alloys 8 per cent copper is considered the economic point to obtain a balance of strength and low specific gravity. An aluminum-copper 92–8 alloy when cast has a tensile strength of 18,000 lb. per sq. in., Brinell hardness of 70, and specific gravity of 2.85. The wrought alloy normally does not contain more than 4 per cent of copper, with usually some magnesium and manganese. Alu-

minum-copper alloys with more than 6 per cent of copper do not roll well.

Zinc and tin in aluminum alloy causes hot-shortness. Silicon adds fluidity but decreases luster. Magnesium forms a silicide with the silicon present and gives age-hardening. Small amounts of manganese are added to inhibit grain growth. Titanium in small amounts gives greater corrosion resistance, but causes brittleness in large amounts. A German alloy, Pantal, contains 0.20 per cent titanium. Iron in very small amounts increases strength, but causes hot-shortness and sets up intercrystalline corrosion. Aluminum-copper alloy is itself subject to intercrystalline corrosion unless protected. See Alclad.

The most commonly used casting alloys contain 7 to 8.5 per cent of copper, 1 to 2 of zinc, and a maximum of 1.7 of other elements, mostly iron. Alcoa No. 112, and S.A.E. No. 33 fall within this range, but British alloy 3-L-11 has less iron and zinc. Alcoa 122 alloy has 10 per cent of copper, 0.2 magnesium, and 1.2 iron. When sand-cast, it has a tensile strength of 22,000 lb. per sq. in., elongation of 2 per cent, and Brinell hardness of 70. Alcoa 195, with 4 per cent of copper as the only alloying element, has a tensile strength, sand-cast and heat-treated, of 31,000 lb. per sq. in., and elongation of 8 per cent. Aluminum-copper casting alloys are made by adding a Hardener alloy to the aluminum. This alloy contains 50 per cent of aluminum and 50 per cent of copper, with a tolerance of plus or minus 2 per cent of either, the impurities being a maximum of 1 per cent of iron, 1 per cent of zinc, and 0.50 per cent of silicon.

For die castings and permanent mold castings, and for special uses such as for automotive pistons, a wide range of aluminum-copper casting alloys are employed. The English alloys B.E.S. No. 362 and B.E.S. No. L8 contain 11 to 13 per cent of copper and are close grained. B.E.S. No. L11 has 6 to 8 per cent of copper, and is classed as a medium hard, ductile alloy. Bohnalite J, with 10 per cent of copper, and Bohnalite B, with 4.5 copper and 0.3 magnesium, are casting alloys of the Bohn Aluminum and Brass Corporation. Bohnalite J, when permanent molded, has a tensile strength of 35,000 to 50,000 lb. per sq. in., and Brinell hardness of 125 to 160.

The most commonly used wrought aluminum-copper alloys are those containing about 4 per cent of copper with a small amount of magnesium to give them age-hardening properties. See Duralumin and Alcoa 17S. Federal specifications for aluminum alloy wrought materials call for 3.5 to 4.5 per cent of copper, 0.2 to 0.75 magnesium, 0.4 to 1.0 manganese. Heat-treated bars of this alloy must have a minimum tensile strength of 50,000 lb. per sq. in., with elongation of 16 per cent. Rolled aluminum alloy comes in tempers of soft, ¼ hard, ½ hard, ¾ hard, and hard.

Aluminum alloy is marketed under a wide variety of trade names, with characteristics varied by slight additions of alloying elements. Benit metal, a patented alloy developed in France, contains 2 per cent of copper, 0.45 magnesium, and 0.27 tungsten. The tungsten adds strength and ductility. Fairey metal, of the British Aluminium Company, Inc., for airplane propeller forgings, is a duralumin-type alloy. Ultralumin is a heat-treatable aluminum-copper casting and forging alloy of Ultralumin, A. G. Permite is the trade name for aluminum alloy of varying compositions produced by Aluminum Industries, Inc. Londal is a general trade name for wrought alloys of the London Aluminium Company, Ltd. Weisalloy is a name applied to sheet aluminum alloy used for partitions and cabinets by the Henry Weis Manufacturing Company. Tennal is the name of casting alloys of the National Bronze & Aluminum Foundry Company. A ductile low-copper wrought alloy produced by the Sheet Aluminum Corporation under the name of Hyb-lum contains about 2 per cent of alloying elements, copper, nickel, silicon, and magnesium. The color is silvery-white, and it takes a high polish resistant to corrosion. The tensile strength ranges from 21,000 to 37,000 lb. per sq. in., depending upon the hardness and heat-treatment. A French alloy, Alferium, has 2.5 per cent of copper, 0.60 magnesium, 0.50 manganese, and 0.30 silicon. A similar German alloy is called Almag. Anodized aluminum is aluminum alloy which has been treated in an electrolytic chemical bath to give it a matt surface of oxide to prevent further corrosion. Anodized aluminum is used for aircraft construction, and was originally called Eloxal in Germany.

**Aluminum-beryllium alloys.** Various patents have been obtained on alloys of beryllium with aluminum. Usually, less than 1 per cent of beryllium is employed, and is supplementary to other alloying elements. Beryllium hardens the metal and improves machining properties. It also increases the tendency to age-harden in castings. German Duralumin and Lautal, with additions of beryllium, have been made. Aluminum-beryllium wrought alloys show strengths up to 100,000 lb. per sq. in.

**Aluminum brass.** There are two distinct types of aluminum brass. The first is a casting brass in which a small amount of aluminum acts as a flux to eliminate impurities and give the brass greater fluidity for intricate castings. The excess of aluminum remaining in the alloy is usually not more than 0.50 per cent. The addition of aluminum also permits the use of higher percentages of lead up to about 5 per cent, making the castings easy to machine. Various grades of wrought brass are also modified with aluminum, producing alloys with properties between the brasses and the aluminum bronzes. Even very slight additions of aluminum improve the oxidation resistance of brasses, and brasses with as little as 0.10 per cent of aluminum owe their bright color to the resistance to oxidation at the extrusion or forging temperature. Larger amounts of aluminum increase the strength and hardness, but greatly decrease the ductility. A 60–40 brass containing 1.0 per cent of aluminum has its strength increased about 30 per cent and its hardness about 25 per cent. An Aluminum brass of the Chase Brass & Copper Company containing 76 per cent of copper, 22 zinc, and 2 aluminum, when annealed, has a tensile strength of 52,000 lb. per sq. in., and an elongation of 70 per cent. It has 23 per cent of the electrical conductivity of copper, and is corrosion-resistant. This alloy, under the name of Ambraloy 927, is marketed by the American Brass Company for condenser tubes. Ad-aluminum, of the Chase Brass & Copper Company, has 82 per cent of copper, 15 zinc, 2 aluminum, and 1 tin. The tensile strength, annealed, is 53,000 lb. per sq. in. and elongation 65 per cent. Alcunic, of the Scovill Manufacturing Company, is a 70–30 brass modified by replacing some of the zinc with 2

per cent of aluminum and 1 nickel. The alloy known in England as High-tensile brass has 76 per cent of copper, 22 zinc, and 2 aluminum. The tensile strength is up to 80,000 lb. per sq. in., and elongation 10 per cent. This alloy is marketed by Revere Copper and Brass, Inc., under the name of Revalon.

**Aluminum bronze.** A copper-aluminum alloy with aluminum as the chief alloying element, either with or without other alloying materials. Plain additions of aluminum to copper increase the tensile strength up to three times that of the original copper, and change the color from red to pale gold. The commercial alloys usually contain from 5 to 10 per cent of aluminum. With more than 7.5 per cent the alloys become increasingly brittle, and cannot be easily cold-worked. The structure changes from homogeneous to duplex at 7.5 per cent aluminum.

All of the alloys are very resistant to corrosion. They can be cast or forged, but the high-aluminum alloys are difficult to machine because of the free aluminum oxide present. The duplex alloys can be hardened by quenching from a high temperature, and then drawn. Aluminum bronze is used for high-strength mechanical parts, especially where nonmagnetic qualities are required. Because of the hard crystals in a soft matrix they are valued for bearings. The corrosion resistance at high temperatures makes them suitable for parts for chemical equipment. The 10 per cent alloys are used for ornamental architectural castings to contrast in color with aluminum-silicon alloys.

A common aluminum bronze with 5 per cent of aluminum has a tensile strength of 65,000 lb. per sq. in., and weighs 0.302 lb. per cu. in. A standard aluminum bronze for castings contains 10 per cent of aluminum and 90 copper. Atlas 90, of Ampco Metal, Inc., has this composition, and has a tensile strength up to 90,000 lb. per sq. in. Ambraloy 928, a wrought alloy of the American Brass Company, contains 92 per cent copper and 8 aluminum. When annealed it has a tensile strength of 60,000 lb. per sq. in. with elongation of 60 per cent, and when hard rolled the tensile strength is 120,000 lb. per sq. in. with elongation of 4 per cent.

Additions of iron to aluminum bronze increase the strength, and the gear bronzes often contain iron. The Copper-aluminum-iron alloys are also used for cast forming dies and for die-casting dies. They have a hardness up to 325 Brinell. The iron also refines the structure and reduces the tendency to self-anneal. McGill metal, of the McGill Metal Company, is the name of a group of these alloys. A typical analysis is 89 per cent copper, 9 aluminum, and 2 iron. This alloy has a tensile strength up to 90,000 lb. per sq. in., elongation 10 to 20 per cent, and Brinell hardness of 160. It is a casting metal, but can be forged and machines about the same as medium carbon steel. A casting alloy used in aircraft engines, with 10 per cent of aluminum and 1 iron, has a tensile strength of 75,000 lb. per sq. in., and Brinell hardness of 100. This is Lumen alloy 11-C of the Lumen Bearing Company, and is Grade B in Federal specifications, Grade A having more iron and less aluminum. U.S. Navy aluminum bronze 46B-186 has 7 to 9 per cent aluminum and 2.5 to 4.5 iron. This is the same as S.A.E. alloy 68, and has a tensile strength of 80,000 lb. per sq. in. Resistac, of the American Manganese Bronze Company, has 9 per cent aluminum and 1 iron. When heat-treated, the tensile strength is 90,000 lb. per sq. in., and the Brinell hardness 180. Atlas 89 is of the same composition and is used for rolling mill gears. Avialite, of the American Brass Company, of a similar composition, is used for die-pressed parts, and for heat-resistant parts such as aircraft engine valves. Ambraloy 930, of the American Brass Company, is a wrought metal with 8 per cent of aluminum and 2.5 iron. The tensile strength is up to 125,000 lb. per sq. in.

Nickel is also used in aluminum bronzes, especially in those containing iron. It increases the corrosion resistance, and produces dense castings suitable for such uses as hydraulic castings, but requires more care in casting. Auromet 55, of the Aurora Metal Company, contains 76 to 80 per cent of copper, 10 to 12 aluminum, 4 to 6 iron, and 4 to 6 nickel. The wrought metal has a tensile strength of 110,000 lb. per sq. in., elongation of 2 per cent, and Brinell hardness of 250.

Small additions of titanium give strength to the aluminum bronzes. The bronzes containing manganese belong to a separate

category. See Super bronze. Lead is sometimes added for bearing bronzes and for worm gears, or for free-cutting casting alloys. Lead reduces the strength rapidly, and only 1.5 per cent is needed for free cutting, though larger additions may be useful to increase frictional qualities. Atlas 10 bronze, of Ampco Metal, Inc., has 9 per cent of aluminum and 9 lead. The tensile strength is 50,000 lb. per sq. in., and Brinell hardness 50 to 60. Calsun bronze, of the American Brass Company, has 2.5 per cent of aluminum and 2 tin. When soft the tensile strength is 50,000 lb. per sq. in. and elongation 30 per cent; when hard-drawn into wire, the tensile strength is 135,000 lb. per sq. in. and elongation 4 per cent.

**Aluminum bronze powder.** Called also Aluminum powder. A flake powder made by a stamping process, and used as a pigment in paints and printing inks, in silvering rubber articles, and as a pigment for plastics. The powder has a high ratio of surface to volume and will ignite easily. It is therefore valued for flares and fireworks. All of the grades used for paint contain a major proportion of very fine, 300- to 400-mesh, particles, and are polished in a revolving drum with a lubricant to give luster and also leafing properties to form a metallic surface in the paint by capillary attraction. Aluminum powder for use in calorizing and for star shells and flares is not flaked and polished, but consists of particles of spherical shape free from grease. This powder is called Granulated aluminum, although this designation is also given to larger Aluminum pellets marketed for metallurgical purposes and made by blowing molten metal or crushing aluminum. Granulated aluminum is also used for making aerated or porous concrete. See Aerocrete. Aluminum powder mixed with iron oxide is used for welding. See Thermit.

**Aluminum-chromium alloy.** Aluminum alloys containing chromium as the chief alloying element. A light-weight, high-strength alloy originally developed by the Stockholm Metallographic Institute, under the name of Cromal, contains 2 to 4 per cent of chromium, with small amounts of nickel and manganese. The tensile strength is up to 60,000 lb. per sq. in. It is corrosion resistant, and suitable for marine equipment and

food machinery parts. The alloy designated as aluminum-chromium alloy in Federal specifications is an aluminum-magnesium heat-treatable alloy with little or no copper, 1.10 to 1.40 per cent magnesium, and 0.30 chromium. The heat-treated wrought material has a tensile strength of 32,000 lb. per sq. in., and elongation of 15 per cent. Alcoa 53S, of the Aluminum Company of America, has 0.25 per cent of chromium, with 1.25 magnesium and 0.7 silicon.

**Aluminum foil.** Sheet aluminum less than 0.005 in. in thickness employed for wrapping in place of the more expensive tin foil. It is more expensive than the lead foil used for wrapping nonedible products, but has a higher luster, although not as high as the tin foil used in fine confectionery wrapping. Aluminum foil as thin as 0.00025 in. is produced by rolling. It comes in 34 thicknesses from 0.006 mm. (0.00024 in.) to 0.200 mm. (0.00787 in.), the thinnest having 43,300 sq. in. per lb., and the thickest 1,169 sq. in. per lb. Colored foil is made by applying lacquers. Foil is also printed or embossed. Alfol is a trade name for aluminum foil in crumpled form used for heat insulation, originally developed by the National Physical Laboratory in England. See also Tin foil and Lead foil.

**Aluminum-magnesium alloys.** A group of alloys which, except with low magnesium, do not have extensive commercial use in the United States. They contain up to 10 per cent of magnesium, and are distinct from the reverse alloys which have high magnesium and low aluminum. See Magnesium alloy. Aluminum-magnesium alloys with high magnesium are for castings and, when they have more than 4 per cent of magnesium, are difficult to cold-work. A 4-per cent alloy has a tensile strength of 25,000 lb. per sq. in., but is hard and brittle. Alloys modified with other elements, however, are used. The German alloy known as Ulmal has 10 per cent of magnesium, 1 silicon, and 0.50 manganese. The tensile strength is 50,000 lb. per sq. in.

Magnesium in very small quantities is employed in aluminum alloys to give heat-treating properties, increasing the strength and hardness by the formation of chemical compounds. See Aluminum alloy. Aldrey, a product of Aluminium Industrie,

A. G., contains only 0.3 to 0.5 per cent of magnesium, with 0.5 silicon and 0.3 iron. It is used for electrical cables. Silmalec, another European alloy, Alcoa 51S, of the Aluminum Company of America, and Bohnalite S51, of the Bohn Aluminum and Brass Corporation, are similar alloys. Alcoa 45, with 1 per cent of magnesium, has also a small amount of manganese as a hardening element.

For heat-treated sand castings, one of the alloys giving the highest combination of strength, toughness, and resistance to impact of all the aluminum group is the one containing 10 per cent of magnesium with the balance aluminum. Alcoa 220-T4, which has this composition, and is the same as S.A.E. alloy 324, has a tensile strength when heat-treated of 45,000 lb. per sq. in., with elongation of 14 per cent and hardness of 75 Brinell. The specific gravity is 2.56.

A casting alloy containing 4 per cent of magnesium is Alcoa 214. It is readily machinable and is corrosion resistant. Aluminum alloy MG-7, of High Duty Alloys, Ltd., is a corrosion-resistant metal containing 6.5 to 7.25 per cent of magnesium, up to 0.60 manganese, and 0.75 iron. The specific gravity is 2.63, and the tensile strength is up to 26 tons per sq. in. Birmabright is the trade name of the Birmingham Aluminum Casting Company, Ltd., for a similar salt-water resistant alloy in cast and wrought form. K. S. Seewasser alloy is a German casting alloy containing 2.25 per cent of magnesium and 0.2 per cent antimony. This alloy forms a protective coating of antimony oxychloride on the surface. All of the high aluminum-magnesium alloys form an anodic film on the outside which prevents further corrosion. They thus are suitable for architectural castings.

**Aluminum-manganese alloy.** Any aluminum alloy containing manganese as the important alloying element, although many other aluminum alloys also contain some manganese which strengthens the aluminum and reduces the tendency to electrolytic corrosion. The amount of manganese is usually very small, the rich alloys, with up to 10 per cent of manganese, being employed only for adding manganese to aluminum. A.S.T.M. and Federal specifications call for 1 to 1.5 per cent of manganese and

97 per cent of aluminum, with small allowable percentages of copper, iron, silicon, and zinc. The minimum tensile strength, soft, is 19,000 lb. per sq. in. and elongation 23 per cent. The hard-drawn metal has a tensile strength of 27,000 lb. per sq. in. and elongation of 4 per cent. Alcoa 3-S, of the Aluminum Company of America, and Bohnalite 53, of the Bohn Aluminum and Brass Corporation, are alloys of this type. The specific gravity is 2.73. Acieral is a European alloy with 1 per cent of manganese and some magnesium and iron.

The addition of 1 to 2 per cent of copper to aluminum-manganese alloys increases the strength and makes forging easier. A U. S. Navy forging alloy has 2 per cent of copper and 1.5 manganese. Aeron, of the Metallbank & Metallurgische Gesellschaft, contains 1 per cent of manganese, 4 copper, and some silicon. It produces sound castings of high strength. Titanite, of the Aluminum Smelting and Refining Company, is an aluminum-manganese alloy containing titanium. The sand-cast metal has a tensile strength of 29,000 lb. per sq. in. with elongation of 6 per cent.

**Aluminum-nickel alloys.** Nickel is employed to replace copper in aluminum alloys, making them stronger and more corrosion resistant and improving the luster. Usually, not more than 6 per cent of nickel is used, with some magnesium, about 0.5 per cent, to make them responsive to age-hardening. An early light-weight bearing metal, under the name of Bersch metal, contained 7 per cent of nickel, but probably also contained other elements to obtain the crystalline structure. Alloy No. 142, a casting alloy of the Aluminum Company of America, contains 4 per cent of copper, 2 nickel, 1.5 magnesium, and a minimum of 90 per cent of aluminum. It has a tensile strength up to 42,000 lb. per sq. in., and Brinell hardness of 90 to 120. Alcoa 32S, a wrought alloy with 12 per cent silicon, 0.8 nickel, 1 magnesium, and 0.8 copper, has a tensile strength of 52,000 lb. per sq. in. in heat-treated forgings. Batterium metal is an aluminum-copper-nickel alloy developed by the British National Physical Laboratory for corrosion-resistant parts. Nickeloy, of the Western Electric Company, has about 94 per cent aluminum, 4 copper, 1.5 nickel, with small amounts of other elements. The cast metal has a tensile

strength of 20,000 lb. per sq. in., and an elongation of 5 per cent. Neonalium is a German alloy containing 6 to 14 per cent of copper, 1 nickel, and small quantities of other elements. The tensile strength is 34,000 lb. per sq. in. The Swiss alloy, Meral, contains 3 per cent of copper, 1 nickel, 0.8 magnesium, and 0.30 manganese. The heat-treated cast metal has a strength of 50,000 lb. per sq. in. See also Y-alloy.

**Aluminum oxide.** An artificial corundum, $Al_2O_3$, made by fusing bauxite in an arc-type electric furnace. When pure, it is a white powder or it forms in colorless crystals. The specific gravity is about 3.75, and the melting point about 3670°F. The high melting point makes it valuable as a refractory material. The crystalline variety is employed as an abrasive and is preferred to corundum because of its purity. Alundum, of the Norton Company, and Aloxite, of the Carborundum Company, are abrasives of aluminum oxide. Some of the various trade names for aluminum oxide abrasives are Aluminoid, Aluminox, Alulion, Alobrant, Alowalt, Lionite, Borolon, Borite, Idilite, Clevite, Natalite, Natumite, Bathite, Hytens, Adamite, Adalox, Metalite, Durundum, Sterlith, Staralox, Excelite, and Orelite.

For abrasive purposes aluminum oxide is used in various grades, depending upon purity. When hard, sharp crystals are required, as for toolroom grinding, the highest grades are employed, but for average use it is generally preferred with some impurities. The crystals are minute, and the larger grain sizes are made up of many crystals, which is a distinctive point from silicon carbide. For abrasive wheels the Bureau of Standards calls for 19 standard grits, ranging from No. 10, the coarsest, to No. 220, the finest. The No. 10 will all pass through a No. 6 screen, and the No. 220 will pass through a No. 140 screen. The standard sizes for abrasive paper are from No. 3½, which is 20 mesh, to No. 5/0, which is 180 mesh, but finer grain sizes are used, to 320 mesh. For abrasive paper the grains are glued to one side of 40-, 70-, and 90-lb. kraft paper. Grinding compounds for valve grinding are likely to be aluminum oxide grains in oil mixtures.

Aluminum oxide is also employed in making refractory linings and crucibles, with 10 to 25 per cent of refractory clay as a

binder. The fused alumina refractories have high strength at elevated temperatures and high resistance to spalling. Aluminum oxide grains are also made up into pellets with a ceramic bond to be used as Catalyst carriers in the chemical industry. The pellets are 40 per cent porous and are acid proof. Alfrax is the trade name of the Carborundum Company for aluminum oxide as a catalyst carrier and as a refractory. See also Alumina.

**Aluminum paint.** A finishing material made of flake aluminum in a vehicle of linseed oil, varnish, gloss oil, or pyroxylin lacquer. It gives a softer surface with linseed oil, but spar varnish vehicles are used for outside work. In lacquers the powder does not leaf, but the paints dry to a hard, metallic surface with a frosted effect useful for some finishes. Powdered or granular aluminum is not suitable for paint. See Aluminum bronze powder. The smooth paints are made with the finer grades of powder, 300 to 400 mesh. Aluminum paint reflects 70 per cent of the light that falls on it, and is therefore useful for painting tanks that must be kept cool. It also radiates heat poorly and is valuable for painting ovens. It is also used for protecting metal against corrosion and, since sand does not adhere to it, it is used for painting foundry patterns.

**Aluminum palmitate.** One of the important mineral soaps. See Mineral soap. A yellow, massive salt, or a fine white powder of the composition $Al(C_{15}H_{42}O_4)_3$, made by heating a solution of aluminum hydroxide and palmitic acid. It is soluble in oils and benzol but insoluble in water, and is used in waterproofing cloth, and in paints as a drier. Another material of the same class is Aluminum resinate, $Al(C_{14}H_{63}O_5)_3$, a brown mass made by heating rosin and aluminum hydroxide. Aluminum oleate, $Al(C_{18}H_{33}O_2)_3$, is the white salt of oleic acid used as a drier. Aluminum stearate is a white or yellowish salt of stearic acid of the composition $Al(C_{18}H_{35}O_2)_3$. It is repellent to water and is valued for waterproofing fabrics and as a drier, and also is employed in waterproof concrete and stucco.

**Aluminum-silicon alloys.** Two general classes of aluminum alloys, the 5 and the 13 per cent silicon, are characterized by

their ease of casting, corrosion resistance, and lightness. The 13 per cent alloy has a specific gravity of 2.64. These high-silicon alloys cast very well even in thin sections, but the strength decreases and they become more difficult to machine as the silicon increases. Additions of copper increase the strength and improve machinability, and also add the property of age-hardening, but decrease corrosion and wear resistance. Slight additions of magnesium also give age-hardening from the formation of $Mg_2Si$.

Architectural aluminum is usually an alloy of about 5 per cent of silicon. It is corrosion resistant, has a fine color, and casts well in fine detail. The 5 per cent alloy has a tensile strength, when quenched and aged, of about 18,000 lb. per sq. in. and an elongation of 3 per cent. It melts at 1150°F. Alcoa 43, of the Aluminum Company of America, and A.S.T.M. alloy No. 3, are 5 per cent alloys. Bohnalite S43, of the Bohn Aluminum and Brass Corporation, is a similar alloy in wrought form. Alcoa 356 has 7 per cent of silicon and 0.3 magnesium, and can be heat-treated.

The 13 per cent alloy has a tensile strength of 24,000 lb. per sq. in., and an elongation of 5 per cent. It is noted for its lightness, ease of casting, wear resistance, and resistance to the action of salt water. But this type of alloy is usually modified with an alkali to refine the grain and increase the strength. Bohnalite U is a 13 per cent alloy, and Alcoa 47 is a 12.5 per cent modified alloy. See Modified Aluminum alloys. Various intermediate alloys, with special properties, are marketed. One type contains about 2.5 per cent of silicon with sufficient magnesium to give heat-treating properties. It is not as corrosion resistant, but is more so than the aluminum-copper alloys.

These alloys may also contain some copper or nickel. A small amount of iron may also be used to add strength, although it decreases ductility. Navy alloy 2 has 4.5 to 6 per cent of silicon, 0.6 copper, 1 iron, and 0.2 manganese. The tensile strength is 17,000 lb. per sq. in. Where higher strength is needed, the copper may be increased to 5 per cent. Alcoa 108, with 3 per cent of silicon and 4 copper, has a tensile strength of 21,000 lb. per sq. in., sand-cast. Apex 400 alloy is a high-silicon alloy of the

Apex Smelting Company used for architectural and marine castings. It was formerly known as Perm-Brite. The tensile strength is about 25,000 lb. per sq. in. and hardness 55 Brinell.

Almasilium is an aluminum alloy of L'Aluminium Français containing 2 per cent of silicon and 1 magnesium. Almelec contains 0.7 magnesium, 0.5 silicon, and 0.3 iron, and does not properly belong to this class. Aludur is an aluminum-silicon-magnesium wrought alloy of the Giulini Werke, A.G. The German heat-treatable wrought alloy known as Constructal has about 1.2 per cent of copper, 1 silicon, 1 magnesium, and some titanium. See Aluminum alloy. Lautal, of the Lautal Walzwerke, contains 2 per cent of silicon, 5 copper, and some magnesium. Its tensile strength is up to 55,000 lb. per sq. in. Although listed with this group, it also properly belongs to the aluminum-copper alloys. Sigmalium, a Belgian alloy, contains 1 per cent of silicon, 4 copper, and 0.7 magnesium. Partinium, a French alloy, has 7.5 per cent of copper, 1 silicon, 2 zinc, and 1 iron. Avional has 4.75 copper, 1.5 silicon, 1 manganese, and 0.5 magnesium. A great variety of complex alloys containing silicon are employed in Europe. The true silicon casting alloys can be welded easily. A 5 per cent silicon welding rod, under the name of Aluminweld, is marketed by the Lincoln Electric Company.

**Aluminum solder.** The alloys ordinarily used for soldering aluminum are tin-zinc combinations with small additions of aluminum and sometimes copper and lead. A solder prepared by the Bureau of Standards contains 86 per cent of tin, 9 zinc, and 5 aluminum. Another contains 78 per cent of tin, 8 zinc, 9 aluminum, and 5 cadmium. These solders have strength and ductility. A solder to melt at about 260°C. contains 29 per cent tin, 67 zinc, and 4 aluminum. Mouray's solder contains 80 to 90 per cent zinc, 6 to 12 aluminum, and 3 to 8 copper. Richard's solder is a yellow brass containing 3 per cent of aluminum and 3 phosphor-tin. The aluminum solders are in the class of hard solders and are applied with a blow torch. Soluminium, a German solder, contains 55 per cent tin, 33 zinc, 11 aluminum, and 1 copper.

**Aluminum steel.** Any steel containing aluminum as the effective element. Aluminum in very small quantities was first

used in Hadfield steels as a deoxidizer. It increases the strength of the steel but, if the residual aluminum is considerable, the steel becomes brittle. Modern aluminum steels are chiefly used for parts to be surface-hardened by nitriding, and usually also contain other elements. See Nitriding steel. Aluminum steels containing nickel, chromium, and molybdenum, even without nitriding, develop high strength and hardness when heat-treated, the nitriding simply forming a thin glass-hard surface.

Another class of aluminum steels containing 2 to 5 per cent of aluminum are heat resistant, and are used for such purposes as engine valves. See Heat-resistant alloys. A cast steel, Circle L18, of the Lebanon Steel Foundry, for heat-resistant parts, contains 7.5 per cent of aluminum, 37.5 chromium, and little carbon. Such a steel, however, is fragile at ordinary temperatures. Aluminum in small amounts is also added to stainless steels for greater resistance to oxidation.

Alumetized steel is steel having molten aluminum sprayed on the surface, and the metal subsequently heat-treated to produce an alloyed surface. Alplate, of the Reynolds Metals Company, is an Aluminum-coated steel, made by subjecting the heated steel to the action of a reducing gas and then passing the steel through an aluminum bath.

**Aluminum-zinc alloys.** A group of alloys containing a considerable proportion of zinc, although important characteristics may depend upon elements other than zinc. The alloys have found greater use in Europe than in the United States. Zinc is a hardener of aluminum, but the alloys are likely to be hot short, and they do not cast as well as other aluminum alloys. With more than 15 per cent of zinc the alloys are very brittle. The general class of these alloys contains from 10 to 14 per cent of zinc, about 3 per cent of copper, and usually some silicon. British engineering specification B.E.F. 2L5 calls for 13 per cent of zinc, 2.7 copper, and the remainder aluminum. The tensile strength is 25,000 lb. per sq. in., and Brinell hardness 100. An American alloy, called Aero metal, contains somewhat more zinc. Alcoa No. 145 contains 10 per cent zinc, 2.5 copper, and 1.2 iron. S.A.E. alloy 31 and B.E.S. alloy 363, for castings, con-

tain 2.25 to 3.35 per cent copper and 12.5 to 14.5 zinc. These alloys have tensile strengths up to 30,000 lb. per sq. in. and are used for crankcases. The Brinell hardness is about 70, and the weight 0.108 lb. per cu. in.

Alneon is a Swiss aluminum-zinc sand-casting alloy containing 70 to 90 per cent of aluminum, 7 to 22 zinc, 2 to 3 copper, and some nickel to give it added heat-treating properties. The tensile strength is 28,000 lb. per sq. in., and the Brinell hardness is up to 150. Skleron, of the Metallbank u. Metallurgischen Gesellschaft, contains 12 per cent zinc, 3 copper, 0.6 manganese, 0.25 silicon, and a very small amount of lithium to form the compound $Li_3Si$ for added strength and hardness.

**Amalgam.** A combination of a metal with mercury. Amalgams are made with gold, silver, copper, tin, lead, and cadmium. They are used for filling where it is not possible to employ high temperatures. A characteristic of amalgams is that when slightly heated they are soft and easily workable, but when set become very hard. A native Silver amalgam found in South America contains from 26 to 95 per cent of silver. Native Gold amalgams are found in California and Colombia, and contain about 40 per cent gold. Native amalgams are chemical combinations of the metals, while some of the artificial amalgams are alloys and others are compounds. Dental amalgams are prepared by mixing mercury with finely divided alloys composed of varying proportions of silver, tin, and copper.

A Mercury-thallium amalgam, with 8.5 per cent of thallium, which freezes at −76°F., is used for thermometers for low readings. Mackenzie's amalgam is a two-part amalgam in which each part is solid but becomes a liquid when the parts are rubbed together in a mortar at ordinary temperatures. One part contains bismuth and mercury, and the other part contains lead and mercury. Sodium amalgam is made in grades containing 2 to 10 per cent of sodium. It is a silvery-white mass, which decomposes water, and is used for producing hydrogen. Potassium amalgam, made by mixing sodium amalgam with potash, is a true chemical compound, and is used for amalgamating with other metals. See also Crilley metal, Cadmium amalgam, Bismuth amalgam.

**Amatol.** A high explosive used as a bursting charge in shells. It is a mixture of ammonium nitrate and TNT. The 50-50 mixture can be melted and poured, and is used for small shells, while the 80-20 mixture is plastic like brown sugar and is used to fill shells above 4.7 caliber. Amatol is hydroscopic and is less sensitive than TNT. It is exploded by detonation. It does not form dangerous compounds with metals except copper and tin.

**Amber.** A fossil resin found buried in Prussia and the countries along the Baltic Sea. It is employed for making varnishes and lacquers, and for ornaments. The original German name for the material was Glassa, and in early writings it is referred to by the Greek word Elektron and the Persian name Karaba. It was also called Vernice by the Italian painters who used it as a varnish resin. Amber came from a coniferous tree now extinct. It is hard, brittle, and tasteless, and dissolves in acids. It is sometimes transparent, but usually semitransparent or opaque with a glossy surface, yellow or orange in color. It takes a fine polish. When rubbed it becomes electrically charged. Amber contains succinic acid in a complex form. Synthetic amber is a phenol-formaldehyde resin mixed with glycerol, camphor oil, or other material. Amberoid is a name given to a type of reclaimed amber made from scrap pieces of amber compressed into a solid cake. Pieces of copal and other resins may be mixed to form amberoid. It has the same uses as amber. Amber oil, distilled from scrap amber, is used in varnish.

**Amethyst.** A violet or purple transparent quartz valued as a gem stone, but also used as pivot bearings in small mechanisms and for needles in recording machines. The color is due to manganese and iron oxides, and becomes yellow on heating. Amethyst has a density of 2.65, and a hardness of 7 Moh. It is composed of alternate right- and left-hand crystals, and gives a rippled fracture. It is the most esteemed of the quartzes as a gem, but the clear specimens are not common.

**Ammonia.** A gaseous compound of the formula $NH_3$. It was originally called Alkaline air and Volatile alkali, and later in water solution by the name of Spirits of hartshorn. Ammonia has

been a by-product in the distillation of coal in gas works, but is now produced by the direct union of nitrogen and hydrogen in the presence of a catalyst. It is readily absorbed by water, which at 60°F. takes up 683 times its own volume of the gas, forming the liquid commonly called ammonia, which is ammonium hydroxide. The absorption power of ammonia is made use of in freezing machines. Ammonia is also used as a solvent, as a deodorant in cleaning, in rubber processing, in medicine, and for surface-hardening, or nitriding, steels. See Nitralloy. Commercial Smelling salts is Carbonate of ammonia. Anhydrous ammonia is purified ammonia gas liquefied under pressure and put up in cylinders. At 20°C. the liquid has a vapor pressure of 122.1 lb. per sq. in. Chlorine unites with ammonia to form chloramines, and if the chlorine is in excess it forms a yellow oil, Nitrogen trichloride, which is highly explosive. Ammonia does not burn in the air, but a mixture of ammonia and oxygen explodes when ignited. A derivative of ammonia, Methylamine, is used in the tanning industry for unhairing skins, and also as a catalyst and solvent in the manufacture of synthetic resins. It is a gas and, like ammonia, is soluble in water and handled in water solution. It is more inflammable than ammonia, a 40-per cent solution having a flash point of 20°F., and the vapors being explosive in air. There are two forms, the Di-methylamine being more effective for unhairing. In water solution a hydrate is formed, $(CH_3)_2NH{\cdot}7H_2O$, which freezes at −16.8°C. It is also marketed in a sulphate solution.

**Ammoniac.** A gum resin from the stems of the *Dorema ammoniacum*, a plant of Persia and India. It has a peculiar fetid odor and an acrid taste. It is used as an ingredient in adhesives. Oil ammoniac is a yellow liquid distilled from the gum. The specific gravity is about 0.890, boiling point 275°C., and it is soluble in alcohol and benzol.

**Ammonium hydroxide.** Also known as Ammonium hydrate, and Aqua ammonia. A colorless, strongly alkaline, and pungent liquid of the composition $NH_4OH$, with a boiling point of 38°C. At 80°F. it contains 29.4 per cent of ammonia in stable solution. It is obtained by distilling gas liquor or by dissolving synthetic

ammonia in water, and is used for the saponification of fats and oils, as a bleaching agent, for cleaning, and for etching aluminum.

**Ammonium nitrate.** A colorless, crystalline explosive of the composition $NH_4NO_3$, made by the action of nitric acid on ammonium hydroxide. The specific gravity is 1.725, melting point 160°C., and decomposing point 210°C. It is soluble in water, alcohol, and alkalies. Ammonium perchlorate is a white, crystalline explosive of the composition $NH_4ClO_4$, made by the action of perchloric acid on ammonium hydroxide. The specific gravity is 1.95, and it is soluble in water. It decomposes on heating.

**Amphibole.** A group of widely distributed minerals of which the fibrous varieties, actinolite and tremolite, furnish some of the commercial asbestos, and Nephrite is the Jade of the Orient. The amphiboles are chiefly metasilicates of calcium and magnesium with iron replacing part of the magnesium. They occur coarse to fine granular, in crystals or compact, and in silky fibers. The specific gravity is 3 to 3.3, and the hardness 5 to 6. The color varies from white to green and black. Much of the asbestos mined in the United States is the amphibole known as Anthophyllite, $(MgFe)SiO_3$, found from Vermont to Alabama. See Asbestos.

**Amyl acetate.** Called Banana oil because of the odor of bananas. A colorless liquid of the composition $CH_3COOC_5H_{11}$, formed by the interaction of amyl alcohol and acetic acid. The specific gravity is 0.876 and boiling point 139°C. It is insoluble in water but dissolves in alcohol and ether. It is a good solvent for resins and tannins and is used in varnishes and lacquers.

**Amyl alcohol.** A colorless liquid of the composition $C_2H_5{\cdot}CH_3{\cdot}CH{\cdot}CH_2{\cdot}OH$, specific gravity 0.8169, and boiling point 128°C. It is made by the distillation of fusel oil, and is used to produce amyl acetate and for lacquers to secure flow, gloss, and resistance to blushing. Tertiary amyl alcohol, $(CH_3)_3{\cdot}$-$C(OH)CH_2$, has a specific gravity of 0.8144, melting point of −12°C., and boiling point of 102°C. Normal amyl alcohol,

$CH_3(CH_2)_4OH$, has a specific gravity of 0.817, and boiling point of 138°C. Fusel oil, or Fermentation amyl alcohol, is obtained as a by-product in the manufacture of ethyl alcohol. The boiling point is 130°C.

**Andradite.** One of the varieties of common garnet, employed for coating abrasive paper and cloth. Its composition is $Ca_3Fe_2(SiO_4)_3$. The color is yellow, green, or brown to black, and the hardness is 6.5. A green andradite known as Demantoid comes from the Ural Mountains, and the choice stones are the Uralian emeralds. See Abrasive garnet.

**Angico.** The wood of the tree, *Piptadenia rigida*, of Brazil, also known as Queen wood and Angico vermelho. It is very hard, with a dense, close grain. The color is reddish brown, and the weight is 70 lb. per cu. ft. Angico is employed where a hard, heavy wood is required, and in cabinetmaking.

**Aniline.** Also known as Amino-benzene. A colorless, oily liquid used in the preparation of dyestuffs, and to produce drugs, perfumes, explosives, flavoring substances, and other materials. It is found in coal tar and bone oil, or is made by the reduction of nitrobenzene. The composition is $C_6H_5 \cdot NH_2$. Aniline boils at 182°C., and solidifies at −7°C. The specific gravity is 1.026. It is soluble in alcohol, ether, and benzene. It is a poison with a powerful effect on the nervous system, and causes decomposition of the blood. Aniline turns brown in the air and is finally oxidized into a resin.

**Animi gum.** A gum resin obtained from the stem of the plant *Hymenoea courbarii*, of Zanzibar and East Africa, and employed in varnishes. It belongs to the group of East African copals, but is distinguished from copal by the ease of solubility in alcohol. The specific gravity is 1.062 to 1.068 and melting point about 245°C.

**Anode metals.** Metals used for electroplating. They are as pure as is commercially possible, uniform in texture and composition, and have the skin removed by machining. They may be either cast or rolled, with the manufacture controlled to obtain

a uniform grain and to exclude foreign material, so that the anode will corrode uniformly in the plating bath. In addition to pure single metals, various alloys are produced in anode form. The usual brass anode is 80 per cent copper and 20 zinc, but other compositions are used; some may contain 1 to 2 per cent of tin. Brass anodes are called Platers' brass. Copper anodes for metal plating are usually hot-rolled oval-shaped bars, 99.9 per cent pure; copper anodes for electrotypes may be hot-rolled plates, electro-deposited plates, or cast plates. Zinc anodes are 99.9 per cent pure. Nickel anodes are 99+ per cent, rolled or cast in iron molds, or 95 to 97 per cent sand-cast. Special anode metals are marketed under trade names, usually accenting the color, hardness, and corrosion resistance, such as Spekwite, of the Special Chemical Corporation, which gives a white plate harder than nickel. See also Cadalyte.

**Anthracite.** Also called Hard coal. A variety of mineral coal found in Wales, France, Saxony, but in greatest abundance in the United States in Pennsylvania. It is distinguished by its semimetallic luster, high carbon content, and high specific gravity, which is about 1.70. The carbon content may be as high as 95 per cent, but the usual fixed carbon content is from 78 to 84 per cent. It gives about 13,200 B.t.u. The best commercial grades of anthracite should have above 90 per cent carbon, 3 to 4.5 hydrogen, 2 to 5.5 oxygen and nitrogen, and only 1.7 ash. Anthracite, when pure and dry, burns without smoke or smell, and thus is preferred to bituminous coal for household furnaces. But the coal will absorb a heavy proportion of water, and commercial coal may be wetted down to add to the weight. Artificial anthracite, used extensively in Europe, is briquetted anthracite with a waterproof coating for use in household stoves. It burns uniformly because of the absence of moisture. Anthracite is graded chiefly by its size, varying from three sizes of very fine grains called silt, rice, and buckwheat, to the largest size of Furnace, or lump, coal. As it comes from the breaker, the proportions are about 8 per cent silt, 9 rice, 15 buckwheat, 10 pea, 24 chestnut, 23 stove, and 8 egg. It is also graded as anthracite and Semianthracite depending upon the ratio of fixed carbon

to volatile matter. When the ratio is 10 to 1 it is anthracite. See Coal, Bituminous Coal, and Lignite.

**Antifreeze compounds.** Also called Radiator compounds. Mixtures employed in the radiators of internal-combustion engines to lower the freezing point to prevent damage from the formation of ice. The requirements are that the compound must lower the freezing point considerably without lowering the boiling point greatly, it must not corrode the metal or deteriorate rubber connections, it must be stable up to the boiling point, and must be readily obtainable. Calcium chloride was formerly used for automobile radiators but corroded the metals. Oils were also used, but the high boiling points permitted overheating of the engine, and the oils soften rubber. Denatured ethyl alcohol is widely used for automobile radiators. Methanol, or wood alcohol, is less corrosive, but is not as available. A 30 per cent solution of ethyl alcohol in water has a freezing point of about 5°F., and a 50 per cent solution freezes at −24°F. Glycerol is also used, a 40 per cent solution lowering the freezing point to about 0°F., and a 50 per cent solution to −15°F. It has the disadvantage of high viscosity, requiring forced circulation at low temperatures, but it does not evaporate. Ethylene glycol lowers the freezing point to a greater extent than alcohol, but it softens rubber and has a higher first cost. Antifreezes are sold under many trade names, such as Pyro, of the U.S. Industrial Chemicals, Inc., with specific gravity of 0.799 and freezing point of −174.1°F. See Ethylene glycol, Freon, Ethyl chloride, Acetamide.

**Antimonial lead.** An alloy composed of from 3 to 10 per cent of antimony with the balance lead, used for storage-battery plates, bullets, type metal, and tank linings. The antimony hardens the lead and increases tensile strength. The usual alloy contains from 4 to 6 per cent of antimony and has about twice the tensile strength of pure lead. Up to about 0.10 per cent of arsenic stabilizes and hardens the alloy. Antimonial lead of the National Lead Company for chemical linings contains 6 to 8 per cent of antimony, weighs 0.398 lb. per cu. in., and melts at 475 to 555°F. Hoyt metal, of the Hoyt Metal Company, contains 6 to 10 per cent of antimony and the balance lead. Antimonial lead is also

used for machine bearings, although for this purpose it usually contains some tin. Alloys containing from 70 to 90 per cent lead, 5 to 20 antimony, and from 2 to 20 tin are used for car bearings under the name of Lining metal. One railroad uses 85.25 minimum of lead, 6 tin, 8 antimony, and 0.5 maximum copper. Dandelion metal, for locomotive crosshead linings, is given in Pennsylvania Railroad specifications as 72 per cent lead, 18 antimony, and 10 tin. See Babbitt metal.

**Antimony.** A bluish-white metal, symbol Sb, having a crystalline scalelike structure. It is brittle and easily reduced to powder. It is neither malleable nor ductile, and is used only in alloys, especially with lead for solder, battery plates, and type metals. The specific gravity is 6.62, and melting point 824°F. It burns with a bluish light when heated to redness in the air. Antimony imparts hardness and a smooth surface to soft-metal alloys and alloys containing antimony expand on cooling, thus reproducing the fine details of the mold. This property makes it useful for type metals. When alloyed with copper it forms a crystalline alloy valued for machine bearings. See Babbitt metal. Antimony is much used in white metals for utensils. See Pewter. Its compounds are also used in the manufacture of wallpaper, fabrics, paper, and paints. Much of the antimony comes from Hunan Province, China, but Mexico, Chile, Bolivia, and Peru are also producers. The chief antimony ore is stibnite, from which it is obtained by roasting out the sulphur and reducing. Antimony is sold in small flat cakes, and the best grades are 99.6 per cent pure.

**Antimony red.** The trisulphide of antimony, $Sb_2S_3$, precipitated from solutions of antimony salts in orange-red crystals, and used as a paint pigment, for coloring red rubber and in safety matches. It is also known as Antimony sulphide and as Antimony sulphuret. The specific gravity is 4.56, and melting point 546°C. The mineral stibnite is an impure form of Antimony trisulphide.

**Antislip metals.** Metals with abrasive grains cast in them, used for floor plates, stair treads, and car steps. They may be iron,

bronze, or aluminum. The abrasive may be sand, but is more usually a hard and high-melting point material such as aluminum oxide. They are marketed under trade names. Alumalun is the name of an aluminum alloy cast with abrasive grains, made by the American Abrasive Metals Company; Bronzalum is a similar product made of bronze.

**Antler.** The bony, deciduous horns of animals of the deer family, used for making handles for knives and other articles. Antlers are true outgrowths of bone, and are not simply hardenings of tissue as are the horns of other animals. Unlike horn, antlers are solid, and have curiously marked surfaces. They are of various shapes and sizes, and are usually found only on the male during the mating season, although both sexes of reindeer and American caribou possess them. They grow in from three to four months, and are shed annually. Antler is imitated by machine carving bone.

**Apitong.** The wood of the tree *Dipterocarpus grandiflorus*, and others of the same family native to the Malay Peninsula, Borneo, and the Philippines. The wood is of a reddish-brown color and weighs 44 lb. per cu. ft. Several million feet of apitong are exported from the Philippines yearly to the United States and Europe to be used as a type of mahogany.

**Aqua regia.** The common name of a mixture of 3 parts of hydrochloric acid and 1 part of nitric acid, or the product obtained by dissolving sal ammoniac in nitric acid. It is a yellow, volatile liquid with suffocating fumes, employed chiefly for dissolving or testing gold, platinum, and palladium.

**Argentine metal.** A silvery alloy employed for making statuettes and small ornaments. A typical alloy contains 85.5 per cent of tin and 14.5 antimony. The Tin-antimony alloys of this class are silvery-white, hard, and make clean-cut castings due to the property of expanding on cooling. An alloy known as Alger metal contains 90 per cent of tin and 10 antimony. These are the soft Jewelry alloys, as distinct from the soft lead-base alloys used for toys. A harder but more expensive jewelry white alloy for ornaments, known as Warnes metal, contains 10 parts

of tin, 7 nickel, 7 bismuth, and 3 cobalt. Kuromi is a Japanese white jewelry alloy composed of copper whitened with tin and cobalt. See also Argental and Rosein.

**Argentite.** An important ore of silver, also called Silver glance. It has the composition $Ag_2S$, containing theoretically 87.1 per cent of silver. It usually occurs massive, streaked black and lead-gray, with a metallic luster and hardness of 2 to 2.5. It is found in Nevada, Arizona, Mexico, South America, and Europe. Argyrodite is another silver ore found in Bolivia, remarkable as a source of the rare metal germanium. When pure, it has the composition $4Ag_2S \cdot GeS_2$, and contains 5 to 7 per cent of germanium. A similar mineral, Canfieldite, found in Bolivia, has 1.82 per cent of germanium and some tin.

**Argon.** A gaseous element, symbol A, occurring free in the atmosphere to the extent of 0.935 per cent. Its liquefying point is about $-187°C$. It is obtained by passing atmospheric nitrogen over red-hot magnesium, forming magnesium nitride and free argon. It forms no known compounds. The density is about one and one-half times that of air. It is employed in incandescent lamps to give increased light and to prevent vaporization of the filament.

**Arsenic.** A soft, brittle, poisonous element of steel-gray color and metallic luster, symbol As. The melting point is 850°C. and specific gravity 4.8. It is allotropic, with metallic and nonmetallic properties, and forms many compounds. When heated in the air, it burns to Arsenious anhydride with white odorous fumes. More than 75 per cent of arsenic is used in insecticides and weed killers, but it also has many industrial uses, especially in pigments. The white, poisonous powder commonly called arsenic is Arsenic trioxide, or Arsenious oxide, $As_2O_3$. When marketed for commercial use, this White arsenic is colored pink to designate it as a poison. The most common ores of arsenic are the arsenical iron pyrites, realgar, smaltite, and orpiment. It is also a by-product from copper smelters, recovered by distillation. Arsenic is added to antimonial lead alloys and white bearing metals for hardening and to increase fluidity, and to copper to

increase the annealing temperature for such uses as automobile radiators. It is also used in lead shot to diminish cohesion.

**Arsenic disulphide.** Also known as Ruby arsenic, Red arsenic glass, and Red orpiment. It is an orange-red, poisonous powder, of specific gravity 3.5, and melting point 307°C., obtained by roasting arsenopyrite and iron pyrites. The composition is $As_2S_2$, and it is employed in fireworks, as a paint pigment, and in the leather and textile industries.

**Arsenopyrite.** Also called Mispickel. The most common ore of arsenic; used also as a source of white arsenic, and directly in pigments and as a hide preservative. The composition is FeAsS, and it occurs in crystals or massive, with a specific gravity of 6.2, and hardness of 5.5 to 6. It has a metallic luster, and a silvery-white to gray-black color. Another source of white arsenic is the copper ore, Enargite, $Cu_2S \cdot 4CuS \cdot As_2S_3$, containing theoretically 48.3 per cent of copper and 19.1 arsenic. It occurs in massive form with a hardness of 3, specific gravity of 4.45, and is gray, with a pinkish variety known as Luzonite. Enargite is commonly intergrown with Tennantite, $5Cu_2S \cdot 2(CuFe)S \cdot 2As_2S_3$, a mineral of a gray to greenish color.

**Asbestos.** The commercial name for several varieties of fibrous minerals. The original source of asbestos was the mineral Actinolite, but the variety of serpentine known as Chrysotile now furnishes most of the commercial asbestos. The rocks occur compact, but the fibers are easily separated and are fine and flexible. The material is shipped as crudes, fibers, and shorts, fully half of the production being shorts. The long fibers are woven into fabrics and rope, and the shorts are compressed with a binding material into paper or board for insulation. The color of the fiber is white to greenish. Short-fiber asbestos is also washed and finely ground for use as a resistant filler for molding plastics. In England this material is known as Micro-asbestos. Asbestos is employed as a heat insulator, and for fireproof garments and curtains or shields. Asbestos fabric for the latter use is usually woven with about 25 per cent of cotton. When woven with fine metallic wire, it is used for brake linings. See Brake

linings. Blue asbestos, from South Africa, is the mineral Crocidolite, $NaFe(SiO_3)_2FeSiO_3$. The classes of Cape asbestos are Chrysotile, Amosite, and Transvaal blue. Amosite comes in white and dark grades. Transvaal blue comes in long fiber and short fiber. American asbestos is graded as Shingle stock, paper stock, cement stock, and shorts. Tremolite is also employed as asbestos. Canada furnishes more than half of all asbestos. Canadian, Vermont, and Arizona asbestos is chrysotile; that from Georgia and the Carolinas is anthophyllite.

Asbestos felt is made by saturating or coating felted asbestos with asphalt. It is used for roofing. Copperclad is the trade name of Johns-Manville for a roofing material consisting of 2-oz. electro-sheet copper bonded to asbestos felt. Corbestos, of the Victor Manufacturing & Gasket Company, used for gaskets resistant to heat and high pressure, consists of sheet metal covered with graphited asbestos, the sheet metal being punched with small tongues to hold the asbestos. Asbeskin, of the Truscon Laboratories, is a plastic compound composed of asbestos fibers and vulcanized oils, used for air-proofing boiler settings. Fibrotex is asbestos mixed with oil and gum, used as a roofing cement. Fiberock, of the Philip Carey Company, is a roofing material consisting of 85 per cent asbestos fibers with a binder and impregnated with asphalt. Industal is a roofing and siding material of the Keasbey & Mattison Company composed of asbestos fibers and portland cement. It is made in corrugated sheets. Asbestos shingles are usually made of asbestos fibers and portland cement formed under hydraulic pressure. Transite, of Johns-Manville, and Linabestos, of the Keasbey & Mattison Company, are wallboards of this class. The specific gravity is about 2.0. They can be worked easily with carpenters' tools. Asbestos lumber, of the Ambler Asbestos Shingle & Sheathing Company, is of the same materials molded in the form of boards for flooring and partitions. These materials will withstand temperatures above 1000° F. Ebonized asbestos is the trade name of this company for asbestos molded with an asphalt binder used for instrument panels. It has high dielectric strength, and can be cut and machined easily. Asbestos millboard is asbestos fibers compressed with a small amount of binder. It comes in sheets.

**Asbestos paper.** A material made of asbestos bonded usually with a solution of sodium silicate. It is fireproof and a heat insulator. For covering steam pipes and for insulating walls it is made in sheets of two and three ply. For wall insulation it is also made double with one corrugated sheet to form air pockets when in place. Thin sheets, 6 lb. per 11 sq. ft., up to 32 lb. (1/16 in.), are employed for gaskets and for electrical insulation. A sheet packing for superheated steam and chemical fittings, marketed under the name of Amblerite by the Keasbey & Mattison Company, is made of asbestos fibers with a resilient binder. Prenite is the trade name of the B. F. Goodrich Company for Neoprene-bonded asbestos sheet used for chemical packings.

**Ash.** The wood of a variety of species of ash trees. These woods vary in their qualities, but are likely to be mixed in commercial shipments. American and Canadian ash come from the tree *Fraxinus americana* and other species; Arkansas ash from *F. platycarpa;* European ash from *F. excelsior;* and Japanese ash from *F. mandschurica*. White ash, *F. americana*, weighs 41 lb. per cu. ft. dry; Red ash, *F. pennsylvanica*, 39 lb. per cu. ft.; and Green ash, *F. pennsylvanica lanceolata*, 44 lb. These woods vary in tensile strength from 11,000 to 17,000 lb. per sq. in. Mountain ash and Black ash, *F. nigra*, are also species of American ash. The latter, formerly used in aircraft construction, has a specific gravity of 0.53 when oven-dried, a compressive strength perpendicular to the grain of 1,260 lb. per sq. in., and shearing strength parallel to the grain of 1,050 lb. per sq. in. White ash has a compressive strength of 2,250 lb. per sq. in. Oregon ash, *F. oregona*, is somewhat lighter and not as strong as white ash. Ash is hard, with a coarse, open grain, and a brownish color. It is tough and elastic but does not withstand exposure well. It is used for handles, wheels, and flooring. European ash is heavier than American ash, and is tough and elastic. It is used for hockey sticks, tennis racquets, and tool handles. Japanese ash, also called Tamo, is browner in color than American ash and has a close grain.

**Aspen.** The wood of the aspen tree, *Populus tremula*, used chiefly for match stems and for making excelsior. The color is yellowish, and it is tough and close grained. The tree is native to

Europe. The American aspen is from the tree *P. tremuloides*, and the lumber is classed as cottonwood.

**Asphalt.** A bituminous, black or brownish substance, solid or semisolid, found in various parts of the world. It consists of a mixture of hydrocarbons, and is related to petroleum. It melts at from 32 to 38°C., and is soluble in turpentine and partly soluble in alcohol. The most noted deposits of asphalt are in Trinidad and in Venezuela. Trinidad asphalt, crude, contains 47 per cent of bitumen, 28 of clay, and 25 of water. Asphalt is used for roofings, insulating varnishes, acid-resisting paints, and for road surfacing. Cold-molding plastics are frequently asphalt with a filler, marketed under trade names. Gummon, of the Garfield Manufacturing Company, is asbestos fibers molded with a bituminous binder. Astrinite is an English compound for molding acid-resistant parts.

Artificial asphalt is the heavy residue from coal distillation, mechanically mixed with sand, chalk, or limestone. Asphalts are known also under other names. Albertite is a natural asphalt found in Nova Scotia. It is jet black, brittle, and yields oil and coke when distilled. See Gilsonite. Rock asphalt, or Bituminous rock, is a sandstone impregnated with asphalt. It is employed for paving and flooring. Kyrock is a rock asphalt from Kentucky. It consists of silica sand of sharp grains and has a bituminous content of about 7 per cent. The crushed rock is used as a paving material.

Flooring blocks are made of various asphaltic compounds. Elastite, of the Philip Carey Company, is a block made of 35 per cent asphalt, 15 fiber, and 50 mineral filler, used for factory floors. Accotile, of the Armstrong Cork Products Company, is a resilient floor tile made of asbestos fiber, mineral pigments, and asphalt binder. It is resistant to moisture, chemicals, and fire. Emulsified asphalt is used as a floor surfacer. Elastex is an emulsified asphalt of the Truscon Laboratories. Ebontex, of the Philip Carey Company, is an emulsified asphalt used for waterproofing concrete tanks. Thermotex, of the same company, is an emulsion mixed with asbestos fibers, used for painting steam pipes. Cut-back asphalt is asphalt liquefied with petroleum

distillates, used for cementing down floor coverings. Amiesite, of the Amiesite Asphalt Company, is asphalt mixed with rubber latex, or is a premixed asphalt to which an aggregate is added for road filling. See also Oil asphalt.

**Auer metal.** An alloy of cerium and iron possessing pyrophoric or sparking properties, used for gas and cigarette lighters. It is named after Auer von Welsbach. It makes a spark when struck with steel. The best sparking results are given with an alloy composed of 35 per cent of iron and 65 per cent of the cerium earths known as misch metal, fused in vacuum and cast into cylindrical sticks. See Misch metal, Kunheim metal.

**Azoimide.** Also called Iminazoic acid. An extremely explosive substance of the composition $HN \cdot N_2$, used in explosives and also for dissolving out gold and other metals. It is made by passing nitrous fumes into a solution of hydrazine sulphate, and is a colorless gas with a peculiar nauseous odor, liquefying at 37°C., and very soluble in water. The Silver azoimide, $AgN \cdot N_2$, is not soluble in water and is very explosive. Barium azoimide, $BaN_6$, explodes with a green flash when heated. See also Lead azide and Mercury fulminate.

**Babbitt metal.** The original name for Tin-antimony-copper white alloys used for machinery bearings, but the term now applies to almost any white bearing alloy with either tin or lead base. The original babbitt, named after the inventor, was made by melting together 4 parts by weight of copper, 12 of tin, and 8 of antimony, and then adding 12 parts of tin after fusion. It consisted, therefore, of 88.9 per cent of tin, 7.4 antimony, and 3.7 copper. This alloy melts at 462°F. It has a Brinell hardness of 35 at 70°F., and 15 at 212°F. Copper hardens and toughens the alloy and raises the melting point. More lead raises the antifriction qualities but softens the alloy. Antimony hardens the metal and forms hard crystals in the soft matrix which improves the alloy as a bearing metal, but only 3.5 per cent of antimony is normally dissolved in tin. In the low-antimony alloys copper-tin crystals form the hard constituent, and in the high-antimony alloys antimony-tin cubes are also present. Parson's white brass,

of the Cramp Brass & Iron Foundries Company, is a Tin-base alloy containing crystals of both SnSb and SnCu. The hardness is 32 to 38 Brinell, coefficient of friction 0.00801, and specific gravity 7.39. The normal amount of copper in babbitts is 3 to 4 per cent, at which point the maximum fatigue-resisting properties is obtained with about 7 per cent of antimony. More than 4 per cent of copper makes the alloy weak at elevated temperatures. As a general-utility bearing metal, the original alloy has never been improved, and makers frequently designate the tin-base alloys of this class as Genuine babbitt. The lead-base alloys may be designated by trade names or as Anti-friction metal. The Anti-friction metal, of the Bunting Brass & Bronze Company, for example, contains 75 per cent of lead, 15 antimony, and 10 tin.

Commercial white bearing metals known generally as babbitt are divided into three classes: Tin-base, with more than 50 per cent of tin, readily hardened with antimony and copper and used for heavy, pounding service; Intermediate, with 20 to 50 per cent of tin, having low compressive strength and more sluggish; Lead-base, made usually from antimonial lead with small amounts of tin and used for light service. Another class might include a wide variety of white soft alloys containing other elements, including arsenic, bismuth, zinc, and cadmium.

Small amounts of lead increase fluidity, but true tin-base metals should not contain more than 1 per cent of lead. Alloys containing up to 1 per cent of arsenic are harder at high temperatures and are fine grained. Zinc increases hardness but decreases frictional qualities. Even minute quantities of iron harden the alloys, and are not used except where zinc is present. Bismuth reduces shrinkage and refines the grain, but lowers the melting point.

Thurston's bearing metal contains from 9 to 10 per cent of copper, about 20 antimony, and the balance tin. Jacana metal contains about 70 per cent of lead, 10 tin, 19 antimony, and a small amount of bismuth. Cadmium, like zinc, increases the strength, hardness, and fatigue resistance, but large quantities lower the bearing qualities, lower the strength at elevated temperatures, and cause corrosion. Some special metals contain less than 1 per cent of cadmium. Husman's alloy, used originally on

the German railways, contains about 74 per cent tin, 11 antimony, 4 copper, 10 lead, and 0.4 zinc. Karmash's alloy is a high-copper metal with some zinc.

S.A.E. babbitt for connecting-rod bearings has 86 per cent of tin, 5 to 6.5 copper, 6 to 7.5 antimony, and not over 0.35 lead. A babbitt of this kind will have a compressive strength up to 20,000 lb. per sq. in., while the high-lead alloys have only 15,000 lb. per sq. in. Babbitts are marketed under many trade names. Leantin is a low-tin, high-lead alloy of the Lumen Bearing Company; Cosmos metal, of the same company, is a lead-base alloy with small amounts of tin and antimony, and Stannum metal is a high-tin alloy for hard-service bearings. Lubeco metal, of this company, is a medium composition babbitt, and Lotus metal, for motor bearings, is a lead-base alloy with higher percentages of tin and antimony. Hoo Hoo babbitt metal, of the National Bearing Metals Corporation, contains no lead, but is a tin-base alloy with copper, nickel, and antimony. Nickel babbitt, of this company, also for heavy loads and high speeds, is a tin-copper-nickel alloy. The compressive strength is 24,600 lb. per sq. in. and Brinell hardness is about 29. Copaloy, of the Michigan Smelting & Refining Company, is a lead-tin-antimony alloy with a small percentage of copper. Bearingoy, of the Williams Alloy Products Company, is a soft lead alloy used where lubrication is poor. Glyco is the name of a group of lead-base alloys of Joseph T. Ryerson & Son, Inc. Satco, of the National Lead Company, is a high melting-point alloy for heavy service. It melts at 788°F. Tinite, of the Ajax Metal Company, is a tin-base metal hardened with copper. Ajax bull, of this company, contains 76 per cent lead, 7 tin, and 17 antimony. Before the invention of babbitt, Copper-antimony alloys had been made but had little commercial use. The 50–50 copper-antimony alloy was a crystalline product of a purple color called by the alchemists Regulus of Venus. See also Antimonial lead, Bahnmetall, Graphited babbitt.

**Badin metal.** A general name for an alloy employed in place of spiegeleisen for making silicon additions to steel and for deoxidizing. It contains 8 to 10 per cent of aluminum, 18 to 20

silicon, 4 to 6 titanium, and the balance iron. It is extremely brittle, and is broken and graded in lumps.

**Bagasse.** The residue left after grinding sugar cane and extracting the juice, employed in making paper and fiber building board. It is also called Megass. Celotex is the trade name of the Celotex Company for this material made into wallboard, paneling, and acoustical tile. Ferox-Celotex is the material treated with chemicals to make it resistant to fungi and termites. Acousti-Celotex is the name for Celotex perforated to increase its sound-absorbing efficiency. The fibers are long, and mat together to form a strong, tough, and absorptive board.

**Bahnmetall.** The original name for a bearing metal consisting of lead hardened by alkali metals. It was covered by a patent assigned to the Metallbank und Metallurgische Gesellschaft. Alloys of this type are called Tempered lead. Bahnmetall contains 0.73 per cent calcium, 0.04 lithium, 0.55 sodium, and the balance lead. The lithium is intended to prevent atmospheric corrosion set up by the calcium. It is made by the electrolysis of the fused alkali salts, using a molten lead cathode. The compressive strength of the metal is up to 30,000 lb. per sq. in. Mathesius metal, of the same company, contains calcium and strontium to form $Pb_3Sr$ crystals. Lurgi metal is another Lead-alkali metal of this company. Another bearing metal, under the name of Noheet metal, contains 1.4 per cent sodium, 0.11 antimony, and a slight amount of tin. Frary metal, of the National Lead Company, is a Lead-calcium-barium alloy containing about 1.5 per cent of calcium and barium. It is used in place of babbitt. These alloys give lower friction loss at economic loads and low temperatures, but are not as efficient as tin-lead alloys above 900 lb. per sq. in. pressure, and have high coefficients of friction at temperatures above 65°C. A European alloy known as Ferry metal has about 0.25 per cent of mercury, with up to 2 per cent of barium and 1 calcium. It is characterized by a soft matrix.

**Baize.** A coarse, loosely woven woolen fabric of plain weave and a short, close nap. It is used for desk and table coverings, box linings, and for bases of instruments. It is usually dyed

green. A thin woolen green felt used for the same purposes is also called by this name.

**Balata.** A gum obtained chiefly from the tree *Mimusops globosa*, of Venezuela, Brazil, and the Guianas. It is almost identical with gutta-percha and is used as a substitute. It is also used for impregnating canvas transmission belting to make it moisture proof. It can be vulcanized with sulphur in the same manner as rubber. For conveyor belts heavy duck is impregnated with balata gum solution, and the belt has high tensile strength and wear resistance. The wood of the balata tree is used for cabinetwork. See Bulletwood.

**Balloon cloth.** A plain-woven cotton fabric used as a base material in making coated fabrics in the construction of balloons and airships. Aluminum sheet has now replaced the material for this use, but it is also used in many other industries. The various grades differ in weight, thread count, and strength. Grade HH, having 120 threads per inch in each direction is most widely used. The U.S. Navy specifications call for a weight of 2.05 oz. per sq. yd. and a tensile strength of 38 lb. per sq. in. in each direction. When several layers are built up and rubberized, they may be on the bias, and the outside layer coated with aluminum paint to reduce the absorption of heat. Gas cell fabric is a single-ply, rubberized balloon cloth coated with viscose and rubber latex, or with a synthetic rubber.

**Balsam fir.** The wood of the coniferous tree *Abies balsamea*, of the United States and Canada. It is brownish white in color, soft, and has a fine, even grain. It is not strong and not very durable, and is used chiefly for packing boxes and light construction. The weight (12 per cent moisture) is 26 lb. per cu. ft.

**Balsa wood.** The wood of the large tree *Ochroma lagopus*, of tropical America. It is one of the lightest of woods, having only about 25 per cent of the weight of spruce, or about 8 lb. per cu. ft. It is used for toys, for life preservers, sounding boards, and where extreme lightness is an important factor and great strength is not required. A Japanese lightweight wood used for

instruments, floats, and where lightness is required, is Kiri, from the tree *Paulownia tomentosa*. It weighs 20 lb. per cu. ft.

**Bamboo.** A genus of gigantic treelike grasses, of the order *Graminaceae*, of which the *Bambusa arundinacea* is the most common species. It grows most commonly in the East Indies and in south Asia. The stems are hollow, jointed, and have an extremely hard exterior surface. They sometimes reach more than a foot in diameter and are often 50 ft. high, growing in dense masses. It is a material of innumerable uses. The stalks are used for making pipes, buckets, baskets, walking sticks, fishing poles, lance shafts, window blinds, mats, arrows, and for building houses and making furniture. The weight is about 22 lb. per cu. ft. Tali bamboo of Java, *Gigantochloa apus*, is used for construction. Betong bamboo is *G. Asper*, and is one of the largest species. Giant bamboo, *Dendrocalamus gigantea*, of Ceylon, grows to a height of 100 ft.

**Barite.** Sometimes spelled Baryte. Also called Heavy spar, and known locally as Tiff. A mineral, which is a natural Barium sulphate, of the theoretical composition $BaSO_4$, used chiefly for the production of lithopone, but also ground and used as a filler for paints, linoleum, rubber, plastics, cloth, and paper. For chemical manufacture it is specified 90 to 95 per cent pure $BaSO_4$, with not over 1 per cent of ferric oxide. Prime white and floated grades are used for coating paper. Artificial barite, Permanent white and Blanc fixe are trade names for white fine-grained precipitated products of U.S.P. or fine paint grades. Micronized barite, for rubber filler, is a fine white powder of 400 to 1,000 mesh. The fine white pigment marketed by the American Zinc Sales Company under the name of Azolith is 71 per cent barium sulphate and 29 per cent zinc sulphide. It is 325 mesh, and the specific gravity is 4.20. The same material of Wishnick-Tumpeer, Inc., is called Sunolith. Barite is widely distributed and especially associated with ores of various metals or with limestones. It occurs in crystals or massive. It may be colorless, white, or light shades of blue, red, and yellow, and transparent to opaque. Its hardness is 3 to 3.5, and the specific gravity is 4.4 to 4.8. It is insoluble in water. Witherite, which is a Barium carbonate,

$BaCO_3$, is employed as a substitute for some filler uses. Much ground crude barite is used in drilling mud for oil wells. Barite is produced in the Western states and from Virginia to Georgia.

**Barium.** A metallic element of the alkaline earth group, symbol Ba. It occurs in combination in the minerals witherite and barite. Barium oxidizes so easily that it is difficult to obtain in the metallic state. It is silvery white in color and can be obtained by electrolysis from the chloride. It oxidizes on contact with the air and decomposes water at ordinary temperatures. Its melting point is 850°C., and specific gravity 3.78. Barium, in the form of its salts, is used as a deoxidizer in purifying alloys of copper, tin, lead, and zinc. Its greatest uses are in its various compounds. It is introduced into lead bearing metals by electrolysis to harden the lead. See Bahnmetall.

**Barium chloride.** A colorless, crystalline substance of the composition $BaCl_2 \cdot 2H_2O$, having a variety of industrial uses but employed in the mechanic arts chiefly for heat-treating baths and for making boiler compounds. The specific gravity is 3.097, and melting point is 860°C. For heat-treating baths for steel parts, it is usually mixed with about 25 per cent of potassium chloride to reduce the melting point. The baths can be raised to almost any temperature required for hardening heats for steels, and be free from fuming.

**Barium nitrate.** A white, crystalline powder of the composition $Ba(NO_3)_2$. It is a barium salt of nitric acid, and is obtained by roasting powdered barite with coke which reduces the barium sulphate to barium sulphide. This is leached out with water and precipitated as a carbonate by the addition of soda ash. The carbonate is then dissolved in dilute nitric acid. The salt is easily soluble in hot water and melts at 575°C. The specific gravity is 3.24. It has a bitter metallic taste. Barium nitrate gives a pale green flame in burning and is used for green signals and flares, and for white flares in which the delicate green is blended with the light of other extremely luminous materials. It is also used as a source of oxygen for pyrotechnic compositions. Sparklers are composed of aluminum and steel filings with

barium nitrate as the oxygen carrier. In Flare powder the time of burning of the aluminum is controlled by the amount of barium nitrate used.

**Basalt.** A dense, hard dark-brown to black igneous rock, consisting of feldspar and augite and often containing crystals of green olivine. It occurs as trap or as volcanic rock. The specific gravity is 2.87 to 3. Masses of basalt are frequently found in columns or prisms, as the celebrated basalt cliffs of North Ireland. Basalt is often wrongly classed as a granite. It is used in the form of crushed stone for paving, for construction, and for making rock wool for insulation. A Russian cast basalt used for electrical insulators is called Angarite. Basalt glass is not basalt, but is pumice.

**Basswood.** The wood of several species of lime trees, *Tilia americana*, *T. heterophylla* (White basswood), *T. glabra*, and *T. pubescens*, all native to the United States and Canada. The European lime tree, *T. cordata*, is not called basswood. Basswood is soft, light in weight, and has a fine, even grain. The weight is 30 lb. per cu. ft. The color is white. It is not very strong. It is used for turning, musical instruments, inner soles of shoes, and a variety of other articles, and for making excelsior. The basswood formerly used for aircraft is from the tree *T. glabra*, and has a compressive strength perpendicular to the grain of 620 lb. per sq. in. The specific gravity is 0.40 when oven dried.

**Bate.** A term employed in the leather tanning industry for materials used to free the skins from lime and to make them soft and flaccid. Dung, largely imported from Asia Minor, was formerly used, but artificial bates are now chiefly used because they are more uniform and are cleaner. Boric acid is sometimes employed for deliming, and gives a silky feel to the leather, but most bates have both a deliming and an enzyme action. Artificial bates are marketed under trade names. Oropon, of Rohm & Haas Company, Inc., is Trypsin carried in wood flour and mixed with a deliming salt. Trypsin is a group of enzymes from the pancreatic glands of animals, and the action on skins is to dissolve the protein.

**Bauxite.** A mineral which is an important ore of the metal aluminum, and is also used in the manufacture of abrasives, aluminum salts, refractories, white cement, and to replace fuller's earth for decolorizing oils. About 50 per cent of the American production is for metallic aluminum, and 30 per cent for abrasives. The chief production is in Arkansas, Georgia, and Alabama. Bauxite is a noncrystalline, earthy mineral, massive or in grains, having a composition $Al_2O_3{\cdot}2H_2O$, containing theoretically 74 per cent of alumina. Cement-making bauxite from Greece contains more than this, but commercial bauxite usually contains 50 to 60 per cent, with some silicon and iron oxides. Brazilian, Arkansas, and Indian ores also contain some titanium oxide, and the Surinam ore has as much as 3 per cent of $TiO_2$. American bauxite has usually a round, pebblelike structure, of white, gray, yellow, or reddish color, and is valued for aluminum production because of its low silica content. Bauxite melts at 1820°C. Diaspore, $Al_2O_3{\cdot}H_2O$, mined in Missouri, and Gibbsite, $Al_2O_3{\cdot}3H_2O$, from the Guianas, are forms of bauxite used for refractories. Filter bauxite is sold in 20–60 and 30–60 mesh grades, and is preferred to fuller's earth for oil-refinery filtering because it can be revivified indefinitely by burning. Calcined bauxite for the abrasive industry is burned bauxite, and runs 78 to 84 per cent $Al_2O_3$. The filter bauxite, or Activated bauxite, is more carefully crushed and screened than other grades, and is sold under trade names such as Porocel and Florite.

**Bearing bronze.** Any bronze used for bearing purposes, but generally referring to bronzes containing lead. As an element in bearing metals lead has been called "the wax of metals," forming the soft matrix or foundation for the hard crystals. The so-called Bearing brasses, used for car journals, are not brass, but usually contain at least 65 per cent of copper, 5 to 10 tin, and up to 30 lead. They seldom contain zinc, but Bush metal, used in England for railway bearings, contains 72 per cent copper, 14 tin, and 14 Yellow metal, or brass ingot metal. The A.S.T.M. bearing bronzes have from 70 to 85 per cent copper, 5 to 10 tin, and 5 to 25 lead, with the zinc kept below 0.50 as an undesirable element. The 85–10–5 bronze has a tensile strength of 28,000 lb.

per sq. in., a compressive deformation limit of 18,000 lb. per sq. in., and a Brinell hardness of 60. The 70–5–25 bronze has a tensile strength of 15,000 lb. per sq. in., and a Brinell hardness of 40. Zinc-bearing bronzes, however, are used for motor shaft bearings where higher strengths are needed. A widely used bronze for electric-motor bearings contains 83 per cent copper, 7 tin, 7 lead, and 3 zinc. This is S.A.E. alloy 660 and Bunting bronze 72. It has a tensile strength of 34,000 lb. per sq. in., compressive limit of 20,000 lb. per sq. in., and hardness of 58 Brinell.

High lead reduces the strength and the hardness, and is difficult to keep in solution, but it improves the antifriction qualities. Plastic bronze, for heavy mill bearings, contains about 30 per cent of lead. Ajax standard plastic bronze, with 64 per cent copper, 5 tin, and 31 lead, has a compressive strength of about 25,000 lb. per sq. in. Addition of small amounts of nickel to bearing bronzes helps to keep the lead in solution and improves the resistance to compression and shock. Iron up to 1 per cent increases the resistance to pounding and hardens the bronze, but reduces the grain size and segregates the lead. See High-lead bronze. Bearing bronzes are marketed under a variety of trade names. Ajax metal, of the Ajax Metal Company, and Johnson bronze, of the Johnson Bronze Company, are names for groups of bearing bronzes of various compositions. Carobronze is the name of a high-phosphorus bronze. Mira metal is a bronze with 16 per cent of lead and 7 antimony, and having small amounts of nickel and tin.

**Bearing materials.** White metals and bronzes are most frequently used for machine bearings, but wood, glass, and various other materials are employed for special uses. Wood is one of the oldest bearing materials, and is still considered an excellent material for large, low-pressure, and slow-speed bearings. The hardwoods are used; since they absorb oil and grease, they require little attention to lubrication. Molded glass of special composition is used for bearings where electrical insulation is required. Laminated molded plastics of fabric base make good bearings as the coefficient of friction is low, and they will operate with only water as the lubricant. They are also electrical

insulators. The crushing strength is from 32,000 to 36,000 lb. per sq. in. Ryertex is the trade name of a plastic bearing material of this type. Nolu is an oil-impregnated wood bearing material of the Nolu Oilless Bearing Company. Woodex is an impregnated wood marketed by the Neveroil Bearing Company for machine bearings. It is maple impregnated with various grades of oil to suit different bearing conditions, and is furnished in the form of bushings. Phosphor lignum, of the same company, is a hardwood oil-impregnated bearing used for textile machinery. Aqualite is the trade name of the National Vulcanized Fibre Company for marine bearings of laminated plastics, but the name also applies to a special shape of the bearing.

**Bearing metals.** Almost any commercial metal can be used for machinery bearings if required, but certain metals and alloys are particularly suitable for bearings, chiefly because of the fact that a proportion of hard crystals is formed in a background, or matrix, of softer metal, supporting the shaft and permitting the free circulation of the lubricant. In the soft metals these crystals are formed largely by the antimony. See Babbitt and Antimonial lead. In the bronzes the crystals consist of a chemical compound of copper and tin, leaving the excess copper as the matrix. Antimony is also used in bearing bronzes, especially for car axles. For very high-pressure hydraulic bearings the hard tin bronzes are used with surface-hardened steel shafts. In general, the tin-base alloys have low coefficients of friction and are tough and capable of withstanding shocks, but the copper bronzes are capable of withstanding heavier loads. Between the two, almost any desired combination can be secured, depending upon the proportions of tin, copper, antimony, lead, or other elements. Although bronzes used for bearings are often called brasses, brass is not much used for bearings since zinc causes sticking, but high-zinc alloys can be used where the zinc forms the matrix. See Fenton's alloy. A high-copper brass known as Tissier's metal, with only about 2 per cent of zinc and no tin, has about 1 per cent of arsenic to give the crystalline structure. In white metals the formation of the structure is affected by the melting and cooling times, and a well-cast alloy of inferior composition

may result in a better bearing than a high-grade alloy that is poorly cast. Some constituents of the alloys have a catalytic action on the lubricants. The presence of tin in any bearing metal reduces the tendency of the lubricating oil to sludge; the presence of alkali metals may have an injurious effect on the oil.

Cast iron is an excellent bearing metal because of the hard carbides, a soft background of iron, and considerable graphitic carbon which acts as a lubricant. The stainless steels are poor bearing metals and tend to stick or seize. Unlike metals are invariably employed for shaft and bearing, and the wear is taken in the bearing. The choice of a bearing metal is usually a compromise of hardness, compressive strength, coefficient of friction, and degree of lubrication. Self-lubricating bearings are of bronze with oil-impregnated wood inserts, or bearing alloys cast or molded with a percentage of graphite. See Graphited metals. Crilley metal is a self-lubricating bearing bronze containing mercury, which is added in the form of an amalgam of bismuth. See Bearing bronzes, Parock, Gramix, Bahnmetall.

**Beech.** The wood of several species of beech trees, *Fagus atropunicea*, *F. ferruginea*, and *F. grandifolia*, common to the eastern parts of the United States and Canada. The wood is strong, compact, fine-grained, durable, and of a light color similar in appearance to maple. The weight is 47 lb. per cu. ft. It is employed for tool handles, shoe lasts, gunpowder charcoal, and for wooden articles such as clothespins. The beech formerly used for aircraft, *F. grandifolia*, has a specific gravity, oven dried, of 0.66, a compressive strength perpendicular to the grain of 1,670 lb. per sq. in., and a shearing strength parallel to the grain of 1,300 lb. per sq. in. The wood may be obtained in large pieces as the trees grow to a height of 100 ft. and a diameter of 4 ft. Antarctic beech, *F. antarctica*, known locally as Rauli, grows extensively in Chile, and is used to replace oak. European beech, *F. sylvatica*, is reddish in color, has a close, even texture, is not as heavy as American beech, but is widely used for tools, furniture, and small articles. New Zealand beech, *F. solandri*, and *F. fusca*, known as Tawhai, are brown in color, and have high strength and durability.

**Beeswax.** The wax formed and deposited by the honey bee, *Apis mellifica.* The bees build combs for the reception of the honey, consisting of two sheets of horizontal, six-angled prismatic cells formed of wax. After the extraction of the honey, the wax is melted and molded into cakes. New wax is light yellow, but turns brown with age. It may be bleached with sunlight or with acids. The specific gravity is 0.965 to 0.969, and the melting point 63°C. Beeswax is used for floor waxes, candles, molded articles, and as a protective material for etching. It is frequently adulterated with paraffin, stearine, or vegetable waxes, and the commercial article may be as low as 50 per cent pure.

**Bell metal.** A bronze chiefly used for casting large bells. The composition is varied to give varying tones, but in addition the castings must be uniform, compact, and fine grained. The standard is 78 per cent of copper and 22 tin. It weighs 0.312 lb. per cu. in. Increasing the copper slightly increases the sonorous tone. This alloy is yellowish red, has a fine grain, is easily fusible, and is used for fine-toned gongs. Large bells are made of 75 per cent copper and 25 tin. "Big Ben" at Westminster, cast in 1856, contains 22 parts copper and 7 tin. Another bell metal, containing 77 per cent copper, 21 tin, and 2 antimony, is harder, giving a sharper tone. An alloy for fire-engine bells contains 20 per cent tin, 2 nickel, 0.1 silicon for deoxidation, and the balance copper. The nickel reduces the tendency to embrittlement from pounding. A bronze marketed by the Lumen Bearing Company for bells contains 80 per cent of copper and 20 tin, deoxidized with phosphorus. Silver bell metal, for bells of "silvery" tone, is a white metal containing about 40 per cent of copper and 60 tin. Silvery bell metal, with the content of tin up to as high as 85 per cent, is used for valves and valve seats in food-product machines.

**Belt dressings.** Compounds employed to soften and improve the surface of belts that are used to drive machinery. They are usually compounded of waxes, degras, fats, tallow, castor oil, fish oil, or corn oil, and may contain sulphonated oils or rosin. Certain oils, such as castor or neat's-foot, act as a lubricant for the leather, but mineral oils are injurious. Rosin is used to give

grip to the belt, but it makes the leather dry and fills the pores so that it cannot be lubricated. Belt dressings are marketed under trade names.

**Benedict metal.** A corrosion-resistant white alloy containing about 85 per cent of copper, 14.5 nickel, and traces of other elements. It is used for condenser tubes, hardware, and parts for chemical machinery. See Cupro-nickel.

**Bentonite.** Also known as Wilkinite. A Colloidal clay used in washing compounds, soaps, emulsions, adhesives, and as a foundry clay. It is a weathered volcanic ash, and is marketed crushed and air-floated, usually in 200- and 300-mesh powder. Bentonite is hydrophilic, or water-swelling, absorbing nearly five times its own weight of water, and is thus valued in certain types of adhesive pastes and emulsions, and as a bonding clay or to increase the plasticity of pottery clays. The Wyoming type has a soapy feel, and is a hydrous silicate of alumina containing about 62 per cent of silica, 22 of alumina, 4 iron oxide, 4 of magnesia and calcium oxide, and 2 of alkali metal oxides. The Mississippi type differs only in physical properties.

**Benzine.** A light product which distills off from petroleum just before the gasoline products. It ranges from $C_5H_{12}$ to $C_6H_{14}$, and is also called Petroleum ether, although true petroleum ether should be the lightest and lowest boiling-point oil. The specific gravity of benzine is from 0.635 to 0.660, and the boiling point limits are from 40 to 70°C. The A.S.T.M. specifications for Petroleum spirits call for a water-white liquid with a flash point not lower than 30°C. Benzine is distinct from benzene. It is used as a fuel in lighters, as a solvent, and as a cleanser. When used as a varnish solvent it is called White spirit. See Naphtha.

**Benzol.** Also called Benzene. A colorless, highly inflammable liquid with a characteristic odor and a composition of $C_6H_6$. It is an aromatic hydrocarbon product of coal tar, obtained in the manufacture of illuminating gas or as a by-product of coke ovens. It is an excellent solvent for waxes, rubber, and other organic materials. It is also used as a fuel for internal-combustion engines, as a cleanser, and for making aniline. The

specific gravity is 0.878, boiling point 97.7°C.; it is insoluble in water but soluble in alcohol. Benzyl alcohol is a colorless liquid of the composition $C_6H_5CH_2OH$, used as a solvent for lacquers, gums, and paints. It boils at 206°C. Benzol is also used as the base for the manufacture of many coal-tar products. Nitrobenzene is a highly poisonous and inflammable liquid of the composition $C_6H_5NO_2$, made by the action of nitric and sulphuric acids on benzene. As a perfuming agent it is sold under the name of Oil of mirbane.

**Benzyl bromide.** A lachrymatory poison used in chemical warfare. It is made by mixing bromide and toluene, and has a composition of $C_6H_5CH_2Br$. It is a colorless liquid with a specific gravity of 1.438, and boiling point of 198°C. The German war gas called T-stoff was benzyl bromide mixed with xylyl bromide and containing also Benzylidene bromide, $C_6H_5CHBr_2$. It has a boiling point of 215°C. See Poison gases.

**Benzyl chloride.** A colorless, aromatic liquid of the composition $C_6H_5CH_2Cl$, used as a lachrymatory poison in chemical warfare, and also in the production of molding compounds. It is made by the chlorination of toluol. The specific gravity is 1.103 and the boiling point 179°C. Benzyl dichloride, $C_6H_5CH{\cdot}Cl_2$, is a heavier liquid with a boiling point of 212°C. Both compounds are thrown in high-explosive shells and disseminated as mists. Benzyl cellulose is a molding material produced by the Imperial Chemical Industries, Ltd. It is made by the action of caustic soda and benzyl chloride on cellulose, and different degrees of benzylation produce different grades of material. It is a cream-colored thermoplastic which can be molded under heat and pressure and dyed in colors. It is resistant to acids and alkalies and is noninflammable.

**Beryllium.** An elementary metal, symbol Be, which belongs to the group of light metals. It was formerly known as Glucinum. The metal is hard, brittle, and crystalline, cannot be rolled or drawn, but alloys well with many other metals to produce very hard alloys. Small amounts of beryllium will harden 18-carat gold to 300 Brinell. The pure metal has a few uses, such as

electrodes of neon signs, windows for X-ray tubes, and atom-smashing cyclotrons. The metal is marketed chiefly as a master alloy of Beryllium-copper, with 12 per cent beryllium and 88 copper. Beryllium has a grayish-steel color and does not corrode easily as an oxidized film protects it from further oxidation. The specific gravity is 1.84, melting point 1285°C., and hardness 6 to 7 on the Moh scale, or hard enough to scratch glass. Beryllium occurs in the emerald and in other forms of the mineral beryl. The ore is abundant, but the metal is expensive to reduce. Beryl usually contains from 6 to 12 per cent of Beryllium oxide, but most ore contains only 1 per cent of metal. The beryl of Ontario has an average of 14 per cent beryllium oxide, or 5 per cent metallic beryllium. The beryl crystals occur in pegmatite dikes, and ¼ to ½ in. in diameter. Pegmatite is the only commercial source of beryl, the secondary minerals Bertrandite, Herderite, and Beryllonite containing only slight quantities of beryllium. Beryllium produced by the Goldschmidt method is 99.5 per cent pure. The metal is employed chiefly for making alloys. Synthetic beryl is made in Europe for use as bearings in watches and instruments. Igmerald is a Synthetic emerald produced by the I.G.F. Artificial beryllium oxide, a colorless crystalline product of the composition BeO, is used as a grinding abrasive for hard metals. This oxide, known as Beryllia, is also used as a deposit on silver articles to protect against discoloration. It is deposited by cathodic treatment from a solution of beryllium salts. The films are invisible, but heavy films give a faint iridescent coloring. Beryllium combines with iron, and can be used for casehardening iron or steel to give an extremely hard case.

**Beryllium bronze.** Alloys of copper and beryllium containing usually not over 3 per cent of beryllium. They are sometimes designated as Beryllium copper, although this term is used to mean the master foundry alloys. The alloys have a bronzelike crystalline structure and were first used in Germany for locomotive bearings. Beryllium bronze is now employed for springs, nonsparking tools, and strong mechanical parts. A beryllium bronze produced by Ampco Metals, Inc., has 2.5 per cent of

beryllium, and has a hardness of 325 to 375 Brinell when heat-treated. Silicon in small amounts is added to beryllium bronze to harden and strengthen the alloy further by the formation of $Be_2Si$. Nickel and cobalt also form chemical compounds with beryllium. The Beryllium copper of the American Brass Company has 2 to 2.5 per cent of beryllium and 0.25 to 0.50 nickel. The soft material has a tensile strength of 70,000 lb. per sq. in., elongation of 45 per cent, and hardness of 110 Brinell; the No. 4 hard with maximum heat treatment has a tensile strength of 193,000 lb. per sq. in., elongation of 2 per cent, and hardness of 365 Brinell. For use as springs it has high fatigue resistance. A Beryllium-cobalt alloy intermediate in characteristics between beryllium bronze and phosphor bronze contains only 0.5 per cent of beryllium, with 2 to 3 cobalt, and the balance copper. Beryllium-nickel, with 2.5 per cent beryllium and the balance nickel, hardens to 600 Brinell when heat-treated. A beryllium nickel for springs has 1.9 per cent beryllium, 0.50 manganese, and the remainder nickel. The tensile strength, cold-rolled and heat-treated, is 200,000 lb. per sq. in. with elongation of 6 per cent. It is noted for high torsional endurance. A 2 per cent cast beryllium bronze used for molds for plastics has a hardness of 365 Brinell when heat-treated. A very small amount of iron, 0.25 per cent, improves the structure of beryllium bronze and increases the hardness. In the castings a small amount of nickel refines the grain and increases the ductility. Wrought beryllium copper is marketed regularly in the form of rods and wire. Vankalite is the trade name of a beryllium-copper alloy used for setting diamonds in drill bits.

**Bessemer steel.** Steel made by blowing air through molten iron. The process was developed by Henry Bessemer in England in 1860. The chemical action between the air and the molten mass increases the temperature, and the air forms the chief fuel as the carbon is oxidized and driven off. The blowing process requires only a few minutes, and the carbon is reduced to 0.04 per cent or less. The lining of an acid converter is made of a highly refractory acid material, usually ganister or mica schist. The converters normally vary from 5 to 25 tons capacity. Acid

Bessemer pig iron should contain about 1 per cent of silicon, but the sulphur and phosphorus should be low since they are not removed in the process. In the final steel a content of 0.09 to 0.13 per cent of phosphorus and 0.075 to 0.15 of sulphur is desired to make machinery steel that is free cutting and not curling, but these amounts are too high for structural steels. The carbon content is regulated by the addition of carbon to the melt. A good acid Bessemer soft steel contains about 0.15 per cent of carbon, 0.40 to 0.80 manganese, and up to 0.08 each of phosphorus and sulphur. The steels have a wide usage for general purposes. For basic Bessemer steel the converter has a basic lining of burned dolomite, and the pig iron used has less silicon to avoid the production of much silica. High-phosphorus pig irons are made into steel by this process as the basic lining aids in the elimination of the phosphorus and sulphur. Lime is also put in at the beginning of the blow. The basic process is employed in England and in Germany, where the product is called Thomas steel. The first nickel steel produced in the United States was made in 1890 by adding about 3 per cent of nickel in a Bessemer converter.

**Birch.** The wood of the birch trees *Betula alba*, the White birch; *B. lenta*, the Sweet birch; *B. nigra*, River birch, *B. lutea*, Yellow birch; and others, grown in North America, Europe, and Asia. Black birch, Russian maple, and Silver birch are other varieties. The wood has a yellow color, is tough, hard, and close textured, and is similar in appearance to maple. Birch is used in construction work for trim and paneling, for furniture, and for turned articles. The lumber usually includes the wood of several species. It has a specific gravity, oven dried, of 0.68, a compressive strength perpendicular to the grain of 1,590 lb. per sq. in., and a shearing strength parallel to the grain of 1,300 lb. per sq. in.

**Birch oil.** A yellowish, poisonous, essential oil with a characteristic birch odor, obtained by distillation from Birch tar, which is a product of the dry distillation of the wood of the white birch tree. The specific gravity is 0.956. It is distinct from the sweet birch oil known as Betula oil, and is

employed in dressing fancy leather, and as a disinfectant and perfume in cleaning solutions and in soaps. It is also used to neutralize odors in organic compounds.

**Bismuth.** An elementary metal, symbol Bi, sometimes occurring native in small quantities. American bismuth is obtained chiefly as a by-product in the refining of lead and copper, and foreign bismuth comes largely from the mineral bismuthinite. Bismuth has a grayish-white color with a reddish tinge, is very brittle, and powders easily. The specific gravity is 9.75, melting point 507°F., and hardness 73 Brinell. The thermal conductivity is less than any other metal except mercury, and the coefficient of expansion is 0.00000731 per deg. F. It is nonradioactive and is the most diamagnetic of all the metals. Bismuth has the property of expanding when changing from the liquid to the solid state, which makes it valuable in type-metal alloys and for small castings where sharp impressions of the mold are needed. Bismuth also lowers the melting point of alloys, and is used in soft solders and in fusible alloys. The metal imparts to lead and tin alloys hardness, sonorousness, luster, and fusibility. High-bismuth white alloys are used for dies for casting plastics. Very fine Bismuth wire used for thermocouples is drawn in glass tubes. Bismuth steel, with a very small amount of bismuth, is used for transformer sheets. It has increased electrical resistance without diminished electrical permeability and lowered hysteresis.

**Bismuth amalgam.** The lustrous, very fluid combinations of the metals mercury and bismuth, used chiefly for silvering mirrors. They are also added to white metals to soften them, and to fusible alloys to lower the melting point. See Crilley metal and Fusible alloys. The binary amalgams of mercury and bismuth are usually too fluid for ordinary use. The usual quaternary alloy has equal parts of bismuth, lead, tin, and mercury, and the proportion of mercury is increased when greater fluidity is desired. A bismuth amalgam containing 90 parts of bismuth, 70 lead, and 8 mercury is used for making "leads" for Lead pencils.

**Bismuthinite.** An ore of the metal bismuth, found in northern Europe, Bolivia, Australia, and in the western parts of the United States. It is a Bismuth trisulphide, $Bi_2S_3$, containing theoretically about 81 per cent of bismuth. It has a massive foliated structure, with a metallic luster and a lead-gray streaked color, and a hardness of 2. The concentrated ore is roasted and smelted with carbon, and the resulting impure bismuth is refined by an oxidizing fusion.

**Bismuth oxychloride.** Also known as Pearl white. A white, lustrous, crystalline powder of the composition BiOCl, employed as a paint pigment. The specific gravity is 7.717. It is insoluble in water. Another bismuth pigment is Bismuth chromate, an insoluble, orange-yellow powder of the composition $Bi_2O_3 \cdot 2CrO_3$. See Pigments.

**Bitumen.** The organic matter contained in asphalt, gilsonite, raphaelite, and other asphaltic and tar products, but the general term also includes the natural asphalt with its content of sand and water. It also includes coal-tar pitch. A characteristic of bitumen is that it is totally soluble in carbon disulphide. Bitumen enamel, used for painting tanks and for waterproofing, is asphalt or bitumen dissolved in a volatile solvent. See Asphalt and Tar.

**Bituminous coal.** Also called Soft coal. A variety of coal with a low percentage of carbon, and easily distinguished from anthracite by the property of losing moisture and breaking up into small pieces. The bituminous coals vary in quality from near lignite to the hard grades near anthracite, called Semibituminous coal. The specific gravity of clean bituminous coal is 1.75 to 1.80. It is found in 28 states of the United States, and the estimated American reserves are 14 hundred billion tons, with a production exceeding 350 million tons annually. It is the coal used almost exclusively for industrial purposes. The best steam coals are the semibituminous grades from West Virginia, Virginia, Pennsylvania, and some parts of the Middle West. The latter is very compact and is extracted in large blocks, called Block coal. Good coal for industrial use should give

13,500 to 14,500 B.t.u. per lb., have from 55 to 60 per cent of fixed carbon, and 30 to 37 per cent of volatile matter; the best grades are in lumps. The fine or powdered coal is called Slack coal.

**Blackbutt.** The name of the wood of several species of eucalyptus trees native to Australia, but now grown in other countries and sometimes used as a substitute for oak. These include *Eucalyptus pilularis* and *E. patens*. The wood is gray or dull-brown in color, is hard, close grained, and dense. The weight is about 58 lb. per cu. ft. It is tough and durable, but is inclined to warp and crack.

**Blackfish oil.** A pale yellow oil extracted from the pilot whale, or dolphin, *Globicephalus melas*, found off the North Atlantic coast as far south as New Jersey. The oil is used as a lubricant for fine mechanisms, in cutting oils, and for treating leather. The product from the head and jaw is of the best quality, and is known as Jaw oil. The saponification value is 290, iodine value 27, and specific gravity 0.929. The blackfish averages 15 to 18 ft. in length, with a weight of about 1,000 lb.

**Bleaching powder.** A name used to designate chloride of lime, but commercial bleaching powder may also be a mixture of calcium hypochloride and calcium hypochlorite. It is employed as a strong disinfectant and for cleansing and bleaching.

**Blister steel.** A name applied to the bars removed from the carbonizing boxes in the process of making steel in the cementation furnace. The surface of the bars is covered with blisters caused by the reaction of the carbon with the iron oxide of the slag. Blister steel has a crystalline fracture decreasing towards the center of the bar where there is less carbon. It is used for rolling into commercial bar iron and shear steel. Shear steel is produced from blister steel by cutting and piling together, heating to a high temperature in a shingling furnace, and rolling or hammering into bars. When cut again into short lengths, piled, welded, and redrawn into commercial bars, it is called double-shear steel. Shear steel was originally the only form of commercial steel.

**Blood albumen.** A glutinous powder used in printing cotton textiles and in making glues. The best grades are clear, pale, amber, and colored powders. It is made from slaughter-house blood by clotting the blood and draining off the albumen. The remaining dark red clot is used for Ground blood, marketed for fertilizer.

**Blown oils.** Fatty oils that have been oxidized by blowing air through them while hot, thereby thickening the oil. They are mixed with mineral oils to form special heavy lubricating oils such as marine engine oil, or are employed in cutting oils. They are also used in paints and varnishes as the drying power is increased by the oxidation. The flash point and the iodine value are both lowered by the blowing. The oils usually blown are rapeseed, cottonseed, linseed, fish, and whale oils. Lardine is the trade name of a blown cottonseed oil used for making lubricants.

**Blue vitriol.** Also called Bluestone. The common name for hydrous Copper sulphate used for coppering steel for layout work, for wet electric battery solutions, for copperplating baths, in dyestuffs, germicides, and in various manufacturing processes. Copper sulphate is marketed in azure-blue crystals of the composition $CuSO_4 \cdot 5H_2O$, with a vitreous luster and metallic taste. It is soluble in water and in alcohol. The specific gravity is 2.284. In its natural form, called Chalcanthite, it is a rare mineral found in arid regions and deposited from the waters in copper mines. It is produced commercially by the action of sulphuric acid on copper or copper oxide.

**Boiler compounds.** Chemicals employed for the internal treatment of water in steam boilers to prevent the formation of scale and the foaming of the water. They are distinct from water softeners that are used to extract the undesirable chemical compounds from the water before it is put into the boiler. Sodium salts are most extensively employed in compounds. They convert the sulphate of calcium and magnesium into sulphate of soda, the calcium and magnesium being precipitated as a sludge which is removed by blowing down. The sodium

sulphate is highly soluble and does not deposit. Most of the boiler compounds sold under trade names contain soda ash and caustic soda. Some also contain trisodium phosphate and sodium silicate, and many contain tannin extracts or some other organic matter. Water softening is generally considered preferable to removal of the scale by compounds, but where this is not possible the content of the compound should be selected to suit the feed-water conditions.

**Boiler plate.** Originally iron or steel plate used for making steam boilers, but now a name in general shop use referring to any iron or soft steel plate or heavy sheet. True boiler plate usually includes the thicknesses from No. 10 gage, approximately 9/64 in., to 2½ in.; but No. 12 gage and thinner are referred to as sheet. The minimum thickness of plate used in practice for boilers is ¼ in. Boiler plate is divided into fire-box, flange, and extra-soft. Fire-box plates should contain not over 0.30 per cent of carbon, 0.30 to 0.50 per cent of manganese, and not over 0.04 per cent each of phosphorus and sulphur. Flange plates should contain less carbon. The tensile strength is from 55,000 to 65,000 lb. per sq. in. A 3 per cent nickel steel is also used for high-pressure boiler plate. It contains from 2.75 to 3.25 per cent of nickel, 0.40 to 0.80 per cent of manganese, and not over 0.20 per cent of carbon. The ultimate strength is above 70,000 lb. per sq. in., and the elongation 26 per cent. It resists corrosion better than ordinary boiler plate. Boiler plate is now also made regularly in manganese steels, and from highly refined ingot irons, such as Toncan iron, containing copper or other elements. For special cases to resist corrosion or for high temperatures, special alloy steels, especially chromium steels, are used. Molybdenum in small quantities is sometimes added to steels for boiler plate to make it resistant to creep at elevated temperatures.

**Bolting cloth.** A fine, strong, silk cloth of very open weave, used industrially for sifting finely pulverized materials. True bolting cloth is made almost entirely on hand looms and comes largely from Switzerland.

**Bone black.** Charred bone or ivory, ground to a fine, silky powder, and used as a pigment, especially for inks. It has a deep, dense, bluish-black color; its depth and tone are valued for engraving inks, but its covering power is much inferior to that of carbon black. It is also used as a decolorizing agent for oils. Bone black is made by calcining bones in airtight retorts after they have been freed from fat and ground to a coarse powder. The specific gravity is 2.6 to 2.8. It has a low carbon content and a very high ash content. The best blacks are treated with acid to remove the lime salts. Federal specifications for bone black for japan pigment require that 97.5 per cent should pass through a 325-mesh sieve. Drop black is the spent bone black from the decolorizing of sugar, which has been washed and reground. It is substituted for bone black. Ivory black, used as a decolorizing agent and for filtering, is made by heating the refuse of ivory working in a closed retort and then grinding fine.

**Borax.** A white or colorless crystalline mineral used as a flux in smelting and soldering, as a scouring and cleaning agent, and as an antiseptic and preservative. It is also used for producing a boronized hard case on steel. Borax is a hydrous Sodium borate of the composition $Na_2B_4O_7 \cdot 10H_2O$. The hardness is 2 to 2.5, specific gravity 1.75, and it begins to melt at 1125°F. It contains 47.2 per cent of water and is readily soluble in water. The borax from California and Nevada known as Colemanite is Calcium borate, and that known as Kernite is another variety of Sodium borate of the composition $Na_2B_4O_7 \cdot 4H_2O$. Borax is found in great quantities in the desert regions of the Western states, and in the Andean deserts of South America. Federal specifications for borax call for not less than 99.5 per cent of hydrous sodium borate in three grades from large crystals to fine white powder.

**Boric acid.** Also called Boracic acid and Orthoboric acid. A white, crystalline powder of the composition $H_3BO_3$, used as a flux in soldering and brazing, for surface-hardening steels, as a preservative and weak antiseptic, in glass and pottery manufacture, and in the tanning industry for deliming skins by forming calcium borates soluble in water. The specific gravity is

1.435, and melting point 1050°F. It is soluble in water and in alcohol. It occurs naturally in the volcanic districts of Italy, and is obtained also from the boron ores of California, Chile, Bolivia, and Peru. See Borax. It is made commercially by adding hydrochloric or sulphuric acid to a solution of borax, and crystallizing.

**Borneol.** Also called Borneo camphor. A white, crystalline substance of the composition $C_{10}H_{18}O$, used as a substitute for camphor in making celluloid. It is obtained from the tree *Dryobalanops camphora* of Borneo and Sumatra. It has an aromatic, pepperlike odor, a specific gravity of 1.01, and a melting point of 208°C. It is soluble in alcohol and slightly soluble in water.

**Bornite.** An important ore of copper. It occurs in massive form having a bronze color which turns purple on exposure. The composition is $Cu_5FeS_4$, having theoretically 63.3 per cent of copper, but usually averaging 55 per cent. It has a metallic luster, and a hardness of 3. Bornite is widely distributed, and mined in Chile, Peru, Canada, and the United States. It is also known as Horseflesh ore, Peacock ore, and Variegated ore.

**Boron.** An element, symbol B, closely resembling silicon. When pure, it is in the form of hard red crystals, or a brownish amorphous powder. The specific gravity of the latter is 2.45. At about 600°C. it ignites and burns with a brilliant flame. It is obtained by the electrolysis of fused boric oxide. Boron is used only in its compounds, the best known being borax and boric acid. In combination with carbon it forms a very hard abrasive. See Boron carbide. Minute quantities of boron are used in steels for casehardening by the nitriding process to form a boron nitride. Boron steels contain only slight additions of boron, as this element makes the metal brittle and hot short. Boron compounds are used as fluxes and deoxidizing agents in melting metals. Colmonoy is the trade name of a Chromium boride, a hard diamond-like crystalline abrasive.

**Boron carbide.** A fine, black, crystalline powder of great hardness used as an abrasive or compressed into drawing dies. It is made by fusing together boric acid and carbon in an electric

furnace. The composition is either $B_6C$ or $B_4C$. The commercial boron carbide of the first composition is crystalline and contains an excess of flake graphite mixed with the carbide. Boroflux, of the General Electric Company, is the trade name of boron carbide with flake graphite. It is used as a deoxidizing material for casting copper, and also as a lapping abrasive since the graphite acts as a lubricant. The amorphous boron carbide marketed by the Norton Company under the name of Norbide is of the second composition and is free of graphite. It is used as a hard abrasive. Boron carbide has a specific gravity of 2.3 to 2.6, and a hardness of a little over 9. It comes as a uniform powder of 150 to 200 mesh.

**Bort.** A name used to designate diamonds of the gem variety but of inferior gem quality that are used for abrasive purposes. It includes stones of a radiating crystallization that will not polish well. South African bort is entirely cull stones from the gem industry. Bort also includes an amorphous variety of diamond in brown, gray, or black colors, known as Black diamonds, and as Carbonados, or Carbons, found in Brazil in association with gem diamonds. Brown borts are much used for grinding, and the amorphous diamonds are extensively used in diamond drills and cutting tools. These diamonds are compact and not so likely to split and chip in service. They vary greatly in quality and hardness, some being actually harder than the rating of 10 on the Moh scale, given as the normal hardness of the diamond. They are found in irregular pieces. But the bort from gem-diamond refuse has largely replaced carbonados for abrasive use because of lower cost. See also Diamond dust.

**Boxwood.** The wood of the tree *Buxus sempervirens*, native to Europe and Asia but also grown in America. It is used for rulers, instruments, engraving blocks, and inlay work. It is light yellow, hard, and has a fine grain and a dense structure which does not warp easily. The weight is about 65 lb. per cu. ft. African boxwood comes from the tree *B. macowani*, of South Africa, and is very similar to boxwood. Cape boxwood, or East London boxwood, and known also as Kamassi wood, is a hard, fine-grained wood from the tree *Gonioma*

*kamassi*, of South Africa. but it does not have the straight grain of boxwood.

**Brake linings.** A term generally referring to the treated and compressed fabric materials for lining the brake bands of motor vehicles and machinery, and not including wood block linings still employed on hoists. Brake linings may be impregnated woven fabric, or they may be compressed fibers cemented together with a heat-resistant binder. The coefficient of friction of asbestos fabric when used against steel is from 0.27 to 0.38, as compared with about 0.16 for cast iron against steel. This coefficient may be increased still further with treated binders, or it may be reduced with interwoven wire. A typical brake lining of this class is made by twisting asbestos yarns with fine wire strands, treating with silicate of soda solution, and then weaving into a fabric. This fabric is impregnated with rubber or frictional binder and subjected to heat and pressure. Brake linings are marketed usually under trade names. Raybestos is the trade name of Raybestos-Manhattan, Inc., for an impregnated lining for brakes and friction clutches woven of asbestos and fine wire and consolidated with a binder under pressure. The coefficient of friction is 0.45. Autobestos, of the Keasbey & Mattison Company, consists of chrysotile fiber molded with a binder. In Germany, aluminum or steel wire fiber, of a diameter of 0.03 mm., is used as a substitute for asbestos in brake linings and is bonded with synthetic rubber.

**Brass.** An alloy of copper and zinc, although some brasses also contain other elements. Brasses are more ductile than corresponding copper-tin alloys, or bronzes, but are not so hard, and do not contain the hard copper-tin crystals that make bronzes valuable as bearing metals. Zinc added to copper causes a progressive lowering of the melting point from the 1949°F. of the 95–5 brass to the 1616°F. of the 50–50 brazing metal. Ten per cent of zinc gives a bronze color, 15 per cent golden; from about 20 to 38 per cent the color is yellow. When the zinc exceeds 45 per cent, the color becomes silvery-white, and the alloy is brittle, rapidly losing the characteristics of brass. The maximum tensile strength is reached at 55 per cent

of copper, and the maximum ductility at about 70 per cent of copper content in the alloy.

Alpha brass is the form of brass having less than 36 per cent of zinc. The zinc is all dissolved in the copper, and the alloy has the structure of copper. It is easily cold-worked. Beta brass, with the zinc between 36 and 45 per cent, contains the compound CuZn. It is the best brass for hot working. Gamma brass, with the zinc above 45 per cent, has $Cu_2Zn_3$ crystals in the alloy, and is not easily worked either hot or cold. Even very slight additions of tin change the structure of brass, adding to the brittleness and causing loss of ductility. See Naval brass. More than 75 per cent of all commercial wrought brass contains about 65 per cent of copper and 35 zinc. See High brass. But the 70–30 alloy is called Standard brass and is widely used for deep drawing. See Cartridge brass. A 60–40 brass weighs 0.3015 lb. per cu. ft., and a 70–30 brass weighs 0.3049 lb. per cu. ft. A 60–40 wrought brass has a tensile strength of 54,000 lb. per sq. in. when annealed, and a Brinell hardness of 72. When cold-drawn it has a tensile strength of 96,000 lb. per sq. in., and a Brinell hardness of 175. The average coefficient of expansion of brass is 0.0000106 in. per deg. F.

Brass is much used as an anticorrosion metal. The American Brass Company uses a 67 per cent copper brass for hot-water pipe; for pipes for highly corrosive water it uses 85 per cent copper red brass. Plumrite is the name of brass marketed by the Bridgeport Brass Company for water pipes. Plumrite 67 has 67 per cent of copper; Plumrite 85, for corrosive conditions, has 85 per cent of copper. Brass containing more than 25 per cent of zinc is subject to season cracking when exposed to the corrosive action of ammonia or some salts.

Although the tensile strength of cold-worked brass is high, the modulus of elasticity is much lower, proportionally, than that of steel. Brass is annealed for drawing and bending by quenching in water from a temperature of about 1000°F. In melting brass for casting, any overheating causes loss of zinc by vaporization, thus lowering the zinc content. Small amounts of antimony overcome this dezincification, and are more effective than arsenic also used for this purpose. Lead in small quantities

improves the cutting qualities of brass, but reduces the ductility and the impact qualities. Iron hardens the alloy and reduces the grain size, making it better suited for forging, but makes it difficult to machine. Manganese increases the strength of brass, and increases the solubility of the iron, and also promotes the stability of aluminum in the alloys. Slight additions of silicon increase the strength of brass, but large amounts promote brittleness, loss of strength, and danger of oxide inclusions.

Simple copper-zinc brasses are made in standard degrees of hardness, or "temper." This hardness is obtained by cold rolling after the last annealing, and the degree depends upon the percentage of cold reduction. When the thickness is reduced one number of the Brown and Sharpe gage, the resulting sheet is known as ¼ hard. Other grades are: ½ hard, ¾ hard, extra hard, spring hard, and extra spring hard. The last is obtained by the reduction of 10 numbers in the final rolling. Degrees of softness in annealed brass are measured by the grain size. The three standard degrees are: Dead soft, soft, and light annealed. See Clock brass, Low brass, Commercial bronze, Nickel brass, Gliding metal, Aluminum brass, Silicon brass, Yellow casting brass.

**Brass ingot metal.** Commercial ingots employed for making brass and bronze castings. The A.S.T.M. designates eight grades. No. 1 grade, the highest in copper, contains 88 per cent of copper, 6.5 zinc, 1.5 lead, and 4 tin, with only slight percentages of impurities. The No. 8 grade contains 63.5 per cent of copper, no tin, 2.5 lead, and 34 zinc. For the production of high-grade castings the ingots must be made by careful sorting of the scrap metals, and the impurities removed by remeltings. An advantage of ingot metal over virgin metals is the ease of controlling mixtures in the foundry; where the ingots have been produced under chemical control, high-grade castings can be made. The most widely used ingot metal is the 85–5–5–5, A.S.T.M. No. 2. It has a tensile strength of about 32,000 lb. sq. in., and is poured at 2075°F. It is used for casting valves, fittings, hardware, and general articles. The Red brass ingot, of H. Kramer & Company, contains 80 to 82 per cent

of copper, 3 to 4 tin, 5 to 7 lead, and the balance zinc. Yellow ingot, for plumbing fixtures, contains 65 per cent of copper, 1 tin, 2 lead, and the balance zinc.

**Brazil wood.** The wood of the trees *Cæsalpinia brasiliensis*, *C. crista*, and *C. echinata*, of tropical America, and *C. sappan*, of Asia. It has a rich, bright-red color and takes a fine, lustrous polish. It is valued for such articles as violins and for fine furniture. The wood was formerly much used as a dyewood and as a pigment, producing purple shades with a chrome mordant and crimson with alum. It is still valued for silk dyeing.

**Brazing metal.** A common name for a red brass alloy, low in zinc, used for the casting of such articles as flanges that are to be brazed on copper pipe. Federal specifications for brazing metal call for 84 to 86 per cent of copper and the balance zinc. Some alloys also contain up to 1 per cent of lead for ease of machining. The alloys are tough and ductile, braze easily, but are difficult to cast. Brazing brass, of the American Brass Company, has 75 per cent of copper and 25 zinc. The brazing brass of the U.S. Navy contains up to 0.3 per cent of lead. Metals for Brazing rods are brasses or bronzes to suit the metal to be brazed. A common brazing rod is the 50–50 alloy with a melting point of 1616°F. Brazing wire, of the Chase Brass & Copper Company, contains 59 per cent of copper and 41 zinc, while the Brazing solder, for brazing high-zinc brasses, has 51 per cent of copper and 49 zinc. Bronze and manganese bronze are used for brazing cast iron and steel. Silicon bronze, naval brass, and phosphor bronze are used for brazing copper, bronze, and galvanized iron. See Welding rod.

**Brick.** The most ancient of all artificial building materials. Bricks are blocks of hard-burned clay, employed for construction. Brick clays are of two classes. The first consists of noncalcareous clays or shales composed of true clay with sand, feldspar grains, and iron compounds, and which when fired become buff, or salmon in color. The second class comprise calcareous clays containing up to 40 per cent of calcium carbonate, and are called Marls. When fired they are yellowish.

Brick clays of the first class are widely distributed. Iron oxide varies from 2 to 10 per cent, and the red color of common brick depends largely on this content. In practice the composition of bricks varies widely. Sand-lime bricks, or silica bricks with lime bond, are used for firebricks. See Firebrick, Refractories, and Chromite. Sand-lime bricks, of sand and lime pressed in an atmosphere of steam, are used for fancy walls. Pressed brick is a stiff "mud" brick made under high pressure to make it homogeneous, and is of increased strength and density. The common standard for building brick size is 8¼ by 4 by 2½ in., but other sizes are also used, especially 8 by 3⅞ by 2¼. Paving bricks are either 3 by 4 by 8½ or 3½ by 4 by 8½ in. Paving brick is hard burned, and is very hard. Bricks are made by machine, the clay being ground and tempered. They are made by pressing soft, stiff, or dry. After drying, the burning is done in kilns at temperatures from 900 to 1250°C. The calcareous clays require a temperature up to 1200°C. to bring about chemical combination. The bricks are sorted according to hardness and color, both largely resulting from their position in the kiln. The hardest bricks are used for paving. The common hard brick has a crushing strength of 5,000 to 8,000 lb. per sq. in., and weighs 125 lb. per cu. ft. Building brick is now produced with great uniformity of strength and color. Various types of ceramic glazes and semiglazes are also employed. Floor bricks are highly vitrified bricks, but for factory floors they may be molded blocks of special composition to resist acids or brines. See Elastite.

**Bristles.** The stiff hairs from the back of the hog, used in making brushes. The best brush bristles do not include hair from the sides of the animals, nor the product from the slaughterhouses, but come from types of semiwild swine grown in cool climates, notably northern China and Russia. Bristles are in form similar to a tiny tube outwardly covered with microscopic scales and filled with fatty substance; they are very resilient. Quality varies according to type of animal, climate, and feeding. The colors are white, black, yellow, and gray. They are graded by locality, color, and length. The very short lengths are used for filler material in molded plastics.

**Britannia metal.** A tin-antimony alloy used largely for utensils. It may be considered as a tin hardened with antimony, although some grades of Britannia metal also contain copper and sometimes small quantities of lead. The color is silvery white with a bluish tinge, but may have a yellow tinge if the copper content is high. It takes a fine polish and does not tarnish easily. When well proportioned it is easily worked by stamping, rolling, or spinning. It is also a casting alloy. It is usually silver-plated with a plate of sufficient thickness to withstand cleaning and scouring. The ordinary composition is very similar to that of some Babbitts, tin 89 per cent, antimony 7.5 per cent, and copper 3.5 per cent. Zinc drosses the metal but is used in the casting alloys for toughening. Iron in small quantities hardens the alloy but makes it brittle. The composition of English Britannia is 94 per cent tin, 5 per cent antimony, and 1 per cent copper. Hanover white metal contains about 87 per cent tin, 7.5 antimony, and 5.5 copper. Dutch white metal has 81.5 per cent of tin, 8.5 antimony, and 9.5 copper.

Queen's metal is a Britannia metal containing a small amount of zinc. A typical composition is 88.5 per cent of tin, 7 antimony, 3.5 copper, and 1 zinc. The zinc helps to strengthen the alloy. Minofor is another grade containing up to 9 per cent zinc and up to 1 per cent iron. When zinc is used in these alloys, the antimony is usually lowered because both metals tend to harden the alloy. Ashberry metal, for tableware, contains some nickel and aluminum. A typical composition is: Tin, 80 per cent; antimony, 14; copper, 2; nickel, 2; zinc, 1; and aluminum, 1. Tutanic metal, a German utensil alloy, has 88 to 92 per cent of tin, up to 3 per cent of copper, and 6 to 7.5 lead. Ludenscheidt plate has about 72 per cent of tin, 24 antimony, and 4 copper, with a trace of lead to increase fluidity. Other mixtures under various trade names are also used, such as Wagner's alloy and Koeller's alloy, the latter containing some bismuth to improve the casting qualities. See also Pewter.

**Bromine.** An elementary substance, symbol Br. It is a dark, reddish-brown liquid, having a specific gravity of 3.188, and boiling point of 58°C. It gives off very irritating fumes, and is

highly corrosive. Bromine is used in the manufacture of gases for chemical warfare, in dyes, in photographic chemicals, and in bromides for a great variety of uses. An important use is with tetraethyl lead as a constituent of ethyl fluid for gasoline. The chief American sources of bromine and of iodine are the salt brines of Michigan and the salt lakes of California.

Bromine never occurs free in nature, but is made by the electrolysis of salt solutions. It occurs in sea water to the extent of 60 to 70 parts per million, or 0.006 per cent, and it is also produced from brine wells. It is marketed chiefly in the form of Ethylene dibromide or other compounds. Another related element obtained also as a by-product from salt brines and from nitrates is Iodine, symbol I, a purplish-black, crystalline, poisonous solid valued in medicine but little used in the mechanic arts. Both iodine and bromine are also obtained by burning seaweed, "Tangle," and treating the ashes. A ton of tangle produces about a pound of iodine. Seaweed burning is done in Scotland, Norway, and Japan. The Chilean production of iodine is as a by-product of the nitrate industry.

**Bronze.** A general name for alloys of copper and tin, and now also applied with a qualifying prefix to alloys of copper with silicon, manganese, and other elements. In the true bronzes, tin is the predominating alloying metal with the copper, but some brasses are called bronze because of their color, or because they contain some tin. Unlike zinc, the tin forms a crystalline structure valued for bearing metals. But tin does not deoxidize copper, and the tin oxide stays in the melt. Small amounts of phosphorus are used to reduce the oxide to give stronger castings. Bronze is essentially a casting metal, while brass is mostly used for rolling or drawing. Aluminum is sometimes used as a deoxidizer, but not more than 0.25 per cent can be added without increasing the hardness and reducing the working properties. Small amounts of zinc are added to give sharper castings free from blow holes. Small amounts of lead make the castings free machining, but reduce the strength.

Bronzes containing more than 90 per cent of copper are reddish; below 90 per cent the color changes to orange-yellow.

Bronzes with more than 10 per cent of tin cannot be forged easily. The maximum strength is with 80 per cent of copper and 20 tin. Ductility rapidly decreases with the increase of tin up to 20 per cent, after which it practically disappears until 80 per cent is reached, when it again increases. Bronzes are subject to "tin sweat" in casting when there is a high proportion of tin. A bronze is hard in proportion to the amount of $Cu_4Sn$ crystals it contains, which depends upon the amount of tin and the rate of solidification. These hard crystals are formed at high temperature and by chilling; softer $Cu_2Sn_2$ crystals are formed at low temperatures. Bronzes have a lower thermal conductivity than brasses. The average coefficient of expansion is 0.0000098. A 90–10 bronze weighs 0.317 lb. per cu. in.; an 80–20 bronze weighs 0.315 lb. per cu. in.

Although a true bronze is a copper-tin alloy, the commercial bronzes are almost always modified. In a 90–10 type of bronze, the zinc is usually from 2 to 4 per cent, and the lead up to 1 per cent. A cast bronze of this type will have a tensile strength of about 40,000 lb. per sq. in., and an elongation of 15 to 25 per cent, with a hardness of 60 to 80 Brinell, those high in zinc being the stronger and more ductile, those high in lead being weaker. Bronzes of this type are called Engineer's bronze in England. For architectural castings the copper may be higher. An old foundry formula for Art bronze called for 97 per cent copper, 2 tin, and 1 zinc. It has a dull red color. Gold bronze, for the same purposes, contains 89.5 per cent of copper, 2 tin, 5.5 zinc, and 3 lead.

In Leaded bronze the hard copper-tin crystals aid in holding the lead in solution. These bronzes are resistant to acids and are used for valves. Merco bronze, of the Merco Nordstrom Valve Company, contains 88 per cent copper, 10 tin, and 2 lead, deoxidized with phosphorus. The tensile strength is 42,000 lb. per sq. in. and elongation 17 per cent. The Journal bronze of the Navy, for bearings, contains 82 to 84 per cent of copper, 12.5 to 14.5 tin, 2.5 to 4.5 zinc, and up to 1 per cent of lead. Federal specifications permit a wide range of variation in tin, zinc, and lead, in ten grades of bronze. The A.S.T.M. designates five grades of bronze casting alloys. Alloy No. 1 contains 85

per cent of copper, 10 tin, and 5 lead; Alloy No. 5 contains 70 per cent of copper, 5 tin, and 25 lead. Bronze containing 95 per cent of copper and 5 tin melts at 2480°F.; the 80–20 bronze melts at 1868°F.

The British Coinage copper, containing 95.5 per cent copper, 3 tin, and 1.5 zinc, is a bronze. Patina, the greenish-brown crust formed on bronze and esteemed as a characteristic of antiquity, is a basic sulphate of copper, usually with oxides of tin, copper, and lead. It is imitated by artificial methods. See Copper acetate. Cothias metal, containing 67 per cent of copper and 33 tin, is a Master alloy, used for adding copper and tin to zinc-base alloys. See High-lead bronze, Nickel bronze, Bell metal, Gear bronze, Aluminum bronze.

**Bronze powder.** Pulverized or powdered bronze, or usually brass, made by a hammering process. The flakes are made by stamping from sheet metal. The compositions vary from 70 parts copper and 30 zinc to 90 copper and 10 zinc. As the metal is worked into thin foil, it becomes harder and breaks into small flakes. Lubricant keeps the flakes from sticking to each other. The powder is graded in standard screens, and is then polished in revolving drums with a lubricant. This gives it the property of "leafing," or forming a metallic film on the paint vehicle. The leaf is also called Composition leaf, or Dutch metal leaf, when used as a substitute for gold leaf. The color varies from yellow to reddish depending upon the proportions of copper and zinc, but the powder may also be dyed. "Flitters" are made by reducing thin sheets to flakes, but are not so fine as bronze powder. A white bronze powder is made from aluminum bronze in the same manner. Bronze powders used as pigments and for bronzing are microscopic flakes, and when used in cheap gold paints and for printing are called Gold powder. Bronze powders cannot replace gold for use in atmospheres containing sulphur, or for printing on leather where tannic acid would corrode the metal. They should pass through a No. 100 screen. See Copper powder, Aluminum bronze powder.

**Broomcorn.** A plant of the sorghum family, *Holcus sorghum*, grown in the Southwest and in Illinois and Kansas, and used

for making brushes and brooms. The jointed stems of the dwarf variety grown in the semiarid regions are 12 to 24 in. long, and the standard brush corn is up to 30 in. long. The fibers are yellow in color, and when dry, coarse and hard. As a brush material they have the objection that they break easily, and are therefore unsuited for mechanical brushes for hard service. Broom root is similar to broomcorn, but is from a different plant, a grass, *Epicampes macroura*, of Mexico. The stems are used for brushes.

**Brush fibers.** Industrial brushes are made from a wide variety of fibers, varying from the fine and soft camel's hair to the hard, coarse, and brittle broomcorn. Bristles from the hog form one of the most common; tampico and piassava fibers are important for polishing brushes. Palmetto fiber, for stiff floor sweeps, is from the cabbage palm tree of Florida. Horsehair, from the manes and tails of horses, is used for brushes. Arenga fiber is a stiff, strong fiber from the leaves of the palm tree, *Arenga saccharifera*, of the East Indies. The finest grades resemble horsehair. Bass, or Raphia, is a coarse fiber used for hard brushes and brooms. The heavier piassava fibers are also known commercially as bass, but bass is from the leaves of the palm tree, *Raphia vinifera*, of West Africa. Crin is from the leaves of a palm of Algeria. Vegetable and animal fibers are not resistant to alkalies and acids and cannot be wetted with them. For such contact, brushes are made with strands of steel, brass, bronze, or other metals.

**Buckram.** A coarse, plain-woven open fabric similar to cheesecloth, but heavily sized with gum or other stiffening material. It is usually of cotton, but may be of linen. It is usually white, or in plain colors, and is employed as a stiffening material, for bookbindings, for shoe inner soles, and interlinings for leather goods.

**Buffing compositions.** Materials used for buffing or polishing metals, consisting usually of dolomitic lime with from 18 to 25 per cent of saponifiable grease as a bond. The lime acts as the abrasive, and in some compositions is partly replaced by

other abrasives such as emery flour, tripoli, pumice, silica, or rouge. Harsher abrasives are used for buffing, or "cutting down," rather than for polishing. Abrasives are selected for combinations of hardness, toughness, and sharpness, from the soft iron oxide to the hard and sharp alumina. Buffing compositions are usually sold under trade names. Metal polishes for hand use are now usually liquids. The pastes, formerly known as Putz cream and Brass polish, contained tripoli or pumice with oxalic acid and paraffin. The liquid polishes now generally contain finer abrasives such as pumicite, bentonite, ground silica, or diatomite, in a soap detergent, together with a solvent such as naphtha, and sometimes pine oil or an alkali.

**Building sand.** Any variety of sand used for concrete other than pavements, or for mortar for laying brick or for plastering. Early specifications called for sand grains to be sharp, but rounded grains are now preferred because of fewer voids in the mixture. Building sand is required to be clean, with not more than 3 per cent of clay, loam, or organic matter. A.S.T.M. requirements are that all must pass through a ⅜-in. sieve, 85 per cent through a No. 4 sieve, and not more than 30 per cent through a No. 50 sieve. For brick mortar all of the sand should pass through a ¼-in. sieve. For plaster, not more than 6 per cent should pass through a No. 8 sieve. Flooring sand for mastic flooring is a clean sand passing through a No. 3 sieve, with 7 per cent passing through a No. 100 screen. Roofing sand is a fine white sand. See Paving sand.

**Building stone.** Any stone used for building construction may be classed as building stone, but the stones, in order of importance, used in the United States are Limestone, granite, sandstone, basalt, and marble. Availability, or a near supply, may determine the stone used in ordinary building, but for public buildings stone is transported long distances. Granite is used for foundation tiers and columns; limestone and sandstone are employed extensively above the foundations. Nearly half of all limestone used is Indiana limestone. Marble has a low crushing strength and is usually an architectural stone. See Granite, Basalt, Limestone.

**Bulletwood.** The wood of the balata tree, *Mimusops globosa*, of the Guianas, and of the gutta-percha tree *M. littoralis*, and other species, of southern Asia. The wood has a deep-red color and a fine, open grain. It is extremely hard, and weighs 66 lb. per cu. ft. It is very durable, and is used in cabinetwork, or where a hard, heavy wood is needed.

**Bunting.** A light-weight, worsted fabric, plain-woven, and dyed in solid colors. It is employed mostly for making flags, for box lining, and other industrial uses. It wears well, and does not fade easily. Cotton bunting is a name given to a thin, soft, flimsy fabric of closer weave than cheesecloth. It is dyed in solid colors, and is used chiefly for cheap flags, decorations, and industrial uses, and fades easily.

**Burlap.** A coarse, heavy cloth made of plain-woven jute, and used for wrapping and bagging bulky articles, for upholstery linings, and as a backing fabric for linoleum. Finer grades are also used for wall coverings. For bags and wrapping, the weave is coarse and irregular, and the color is natural or tan. The coarse grades are sometimes called Gunny in the United States, but Gunny is the general name for burlap in Great Britain. Dundee, Scotland, is the important center of burlap manufacture outside of India. Burlap is woven in widths up to 144 in., but 36, 40, and 50 in. are the usual widths. Hessian is the name of a plain-weave finer burlap, originally a rough cloth made from flax. When dyed in colors it is used for linings, wall decoration, and for upholstery. Brattice cloth is a very coarse, heavy, and tightly woven jute cloth, usually 20 oz. per sq. yd., used for gas breaks in coal mines; sometimes a heavy cotton duck is used for the same purpose and designated with the same name.

**Busheled iron.** An inferior grade of iron or steel made by heating scrap iron and steel pieces together in a hearth furnace, and then forging and rolling into bars. This metal is not uniform in quality, due to the mixture of various grades of metals and because of the unreliability of the welding together. It can be used, however, for many general purposes and finds use in wartime or in isolated places.

**Butyl alcohol.** A colorless liquid used chiefly as a solvent for pyroxylin lacquers, molding compounds, paints and varnishes. There are four forms of this alcohol, but only the normal butyl alcohol is important commercially. Normal butyl alcohol has the composition $CH_3(CH)_3OH$, and is made by the fermentation of glycerol. It has a specific gravity of 0.814 and boils at 117°C.

**Cadmium.** A silvery-white crystalline metal, symbol Cd. It is employed in soft solders and fusible alloys, for hardening copper and for electroplating. Its compounds are used as pigments. Cadmium resembles tin and gives the same characteristic cry when bent. It is obtained chiefly as a by-product of the zinc industry, and about half the production is in the United States. The only commercial ore of the metal is Greenockite, CdS, which contains theoretically 77.7 per cent of cadmium. The mineral occurs in yellow powdery form in the zinc ores of Missouri. Cadmium has a specific gravity of 8.6, is very ductile, and can be readily rolled or beaten into thin sheets. A small addition of zinc makes it brittle. It melts at 608°F., and boils at 1580°F. The metal is marketed in small round sticks 12 in. long. It is also sold in variously shaped anodes for electroplating. Electrolytic cadmium is 99.95 per cent pure. For a corrosion-resistant covering for iron or steel a cadmium plate of 0.0003 in. is equal in effect to a zinc coat of 0.001 in., and gives a silvery-white color similar to that of tin, but harder than tin. Cadalyte is a trade name of the Grasselli Chemical Company for a process and patented cadmium salt for the electro-deposition of cadmium on metal articles. Udylite is the name of a patented process, anodes, and salts for cadmium plating, marketed by the Udylite Process Company. Cadmium bronze is a copper alloy containing from 0.5 to 1.2 per cent of cadmium used for telephone and trolley wire. It has high strength and wear resistance. Hitenso is a cadmium bronze produced by the American Brass Company for overhead wires. It has 35 per cent greater strength than hard-drawn copper, and 85 per cent of the conductivity of copper. Cadmium copper is also a name given to copper containing 0.5 to 1.0 per cent of cadmium. The cadmium copper known in

England as Conductivity bronze, used for electric wires, has 0.8 per cent of cadmium and 0.6 tin. The tensile strength, hard drawn, is 85,000 lb. per sq. in., and the electrical conductivity is 50 per cent that of copper.

**Cadmium amalgam.** Also called Evans' metallic cement. A silvery-white compound of cadmium and mercury, which softens at about 100°F., and can be kneaded like wax. It is made by heating the mercury and introducing the cadmium in the form of thin sheet. Its composition is $Cd_5Hg_8$, with about 74 per cent of mercury; the excess of mercury separates out on standing. Cadmium amalgam remains soft for a considerable time, and finally becomes hard and crystalline. It is used for filling holes in metal where it is not desired to use heat. Tin or bismuth may be added. Amalgams with an excess of cadmium are ductile, and can be hammered out into thin sheet.

**Cadmium solder.** A tin-lead solder containing cadmium, or a solder composed of lead and cadmium, the latter replacing the tin. A solder containing 80 per cent of lead, 10 of tin, and 10 of cadmium has about the same strength as a 50–50 tin-lead solder and has greater ductility. It is, however, darker in color due to the greater proportion of lead. Cadmium solders may contain as much as 90 per cent of lead with 5 per cent of tin, and 5 of cadmium, or 10 per cent of cadmium without the tin. Cadmium solders are hard, have low melting points, are usually cheaper in price than tin solders, and have the same uses as tin-lead solders; they have the disadvantage of corroding and blackening, and are therefore not favored for electrical work. In Germany Cadmium-zinc solder is used, but only because of the scarcity of tin. See Solder. A cadmium solder with 72 per cent of tin and 28 of cadmium is used to solder magnesium.

**Caesium.** Also spelled Cesium. A rare elementary metal, symbol Cs. It is the most electropositive of all the elements. It resembles rubidium and potassium in appearance, being silvery white and soft. It oxidizes and blackens easily in the air and ignites at ordinary temperatures, and it decomposes water with explosive violence. For these reasons it must be kept in a

vacuum. The specific gravity is 1.88, melting point 26°C., and boiling point 670°C. The chief source of the metal is the mineral pollucite. Due to its rarity it has yet no application in alloys. It is used on the filaments of radio tubes to increase sensitivity. The caesium, in the form of Caesium chloride, CsCl, interacts with the thorium of the filament to produce positive ions. In photoelectric cells caesium chloride is used for a photosensitive deposit on the cathode. All metals emit electrons when struck with ultraviolet light, but caesium releases electrons under the action of ordinary visible light, and its color sensitivity is higher than that of other alkali metals. It is also used in low-voltage tubes to scavenge the last traces of air.

**Calamine.** An ore of the metal zinc, found in New Jersey, Pennsylvania, Virginia, Missouri, and in Europe. Calamine was formerly mixed directly with copper in the furnace in making brass, but the ore usually contains less than 3 per cent of zinc, and is concentrated to from 35 to 45 per cent and then roasted and distilled. Calamine is a silicate of zinc, $H_2(Zn_2O)SiO_4$. It is a mineral occurring in crystal groups of a vitreous luster, and may be white, greenish, yellow, or brown in color. The hardness is 4.5 to 5, and the specific gravity is 3.4. It occurs often with Smithsonite, another zinc ore.

**Calaverite.** An ore of gold. It is a Gold telluride, $AuTe_2$, containing 44 per cent of gold, and found with Sylvanite in Colorado, California, and Western Australia. Its structure is usually granular, with a metallic luster, a silvery-white color with gray streaks, and a specific gravity of 9.35. Its hardness is 2.5. It is easily fusible.

**Calcite.** One of the most common and widely diffused minerals, and used for the making of lime for mortars and cements. It also includes the limestones used extensively as building stones. Calcite occurs in the form of limestones, marbles, chalks, calcareous marls, and calcareous sandstones. It is a calcium carbonate, $CaCO_3$. Its specific gravity is 2.72 and hardness 3. It is usually white or colorless, or tinted with impurities. When limestone is heated to about 1000°F. it loses

its carbonic acid, and is converted into quicklime. See Lime, Chalk, Marble.

**Calcium.** A metallic element, symbol Ca, belonging to the group of alkaline earths. It is one of the most abundant substances, occurring in limestones and other minerals. It is obtained in metallic form, 98.6 per cent pure, by electrolysis of the fused anhydrous chloride; by further subliming it is obtained 99.5 per cent pure. In lump or stick form it is used as a deoxidizer and for removing sulphur from nonferrous alloys. It has a strong affinity for oxygen and many other elements. Natural calcium compounds are used in melting iron. See Dolomite. Calcium is also used as a hardener for white metals. See Frary metal. Calcium silicide is used in making special steels to inhibit carbide formation, and calcium-copper is a Desulphurizing alloy. At the temperature of molten steel it volatilizes and leaves no residue in the steel. Calcium metal is light yellow in color. When heated in the air it burns with a brilliant white light. The specific gravity is 1.55. Many compounds of calcium are used industrially.

**Calcium carbide.** A hard, crystalline substance of a grayish-black color, used for the production of acetylene gas for welding torches and lighting. It was discovered in 1892, and is made in the electric furnace by reducing lime with coke. The specific gravity is 2.26. Its composition is $CaC_2$, containing theoretically 37.5 per cent of carbon. When water is added to calcium carbide, acetylene is formed, leaving a residue of slaked lime. Chemically pure carbide will yield 5.83 cu. ft. of acetylene per pound of carbide. Federal specifications require not less than 4.5 cu. ft. of gas per pound. Calcium carbide is marketed in four size grades from "lump," which is 3½ in. to 2 in., to "quarter," which is of fineness below ¼ in.

**Calcium chloride.** A white, crystalline, lumpy substance of the composition $CaCl_2$, employed for fire-proofing paints, in quenching solutions for heat-treating steel, for accelerating the setting of concrete, and to keep it from freezing in cold weather. From 2 to 4 per cent is used for quick-setting concrete. Larger quantities decrease the strength of the concrete. It is also

employed for spreading on gravel or macadam roads to aid in surfacing. The specific gravity is 2.152. It is soluble in water, and is highly hygroscopic and deliquescent, which causes it to retain enough moisture to act as a stabilizer on roads. The commercial product usually contains only about 75 per cent of $CaCl_2$, with the balance water of crystallization. Calcium chloride was formerly used as an antifreeze mixture for automobile radiators, but it corrodes the metals. It is used as an antifreeze in water in fire tanks, sodium chromate being added to retard corrosion. One pound of calcium chloride per gallon of water lowers the freezing point to 25°F., and 3 lb. to −9°F. Calcium chloride mixtures are sold under various trade names. Temperite, of the Truscon Laboratories, is a calcium-chloride antifreeze for concrete marketed in liquid or dry form. Lithium chloride, LiCl, is used in solution form in sprays for dehumidifying air for industrial drying and for air conditioning. Calcium chloride is obtained from natural salt brines, or as a by-product of the Solvay soda ash process.

**Calcium-lead alloys.** Lead hardened with very small quantities of calcium is employed for bearing metals. The amount of calcium is usually less than 1 per cent. The calcium forms a chemical compound, $Pb_3Ca$, with part of the lead, and forms crystals in the lead matrix. The latter is also harder than pure lead. Calcium-lead has a Brinell hardness up to 35, and compressive strength of about 25,000 lb. per sq. in., being superior in that respect to high-tin bearing metals. It has the disadvantage, however, of being difficult to melt without oxidation, and is subject to corrosion. The melting point is higher than other white metals, about 370°C., and it retains its bearing strength at more elevated temperatures than babbitts. Calcium-lead, with about 0.04 per cent of calcium, is used as a lead cable sheath alloy to replace antimonial lead. It has increased fatigue endurance. Barium is also used in this same manner with lead. Calcium-lead, with as little as 0.1 per cent of calcium, is also used for Grid metal in storage batteries, and has a lower rate of self-discharge than antimonial lead. See Bahnmetall.

**Calcium molybdate.** A salt of molybdenum used in place of ferromolybdenum for adding molybdenum to steel. It is made by roasting molybdenite to form molybdenum trioxide and adding lime. It contains 60.75 per cent of $MoO_3$ and 23.3 per cent of lime. The formula is $CaMoO_4$. It is added directly to the molten steel, but not in the ladle. The salt is sold on the basis of molybdenum content. Molyte is the trade name of the Molybdenum Corporation of America for a patented mixture of calcium-molybdenum oxides with a flux. It is heavier and sinks readily in the molten steel.

**Calcium-silicon.** An alloy of calcium and silicon used as a deoxidizing agent, and for the elimination of sulphur in the production of high-grade steels and cast irons. It is marketed by one producer as "low-iron," containing 22 to 28 per cent of calcium, 65 to 70 per cent of silicon, and a maximum of 5 per cent of iron; and as "high-iron," containing 18 to 22 per cent of calcium, 58 to 60 of silicon, and 15 to 20 of iron. It comes in crushed form and is added to the molten steel. Calcium-aluminum-silicon, for deoxidizing and degasifying steel, contains 10 to 14 per cent calcium, 8 to 10 aluminum, and 50 to 53 silicon. Calcium-manganese-silicon contains 17 to 19 per cent calcium, 8 to 10 manganese, 55 to 60 silicon, and 10 to 14 iron.

**Calorene.** The trade name of a gas obtained by breaking down ethyl alcohol. It is marketed in steel cylinders under high pressure, and is used chiefly for flame cutting torches. Calorene consists mostly of ethylene, $C_2H_4$, and gives a low-temperature flame when burned with oxygen.

**Cameline oil.** Also called Dodder oil, or German Sesame oil. A light-yellow oil having a peculiar pungent odor, and used as an adulterant of rapeseed oil, which is employed in quenching baths and in lubricants. It is obtained from the German plant *Camelina sativa*, the seeds yielding 35 per cent of the oil. It contains oleic and palmitic acids, and also erucic acid, which is characteristic of rapeseed oil.

**Camel's hair.** The fine woolly hair from the neck and back of the camel, employed industrially for fine brushes for painting.

Most of the fiber comes from Arabia and Persia, and the bulk of it goes into the weaving of fabrics. The natural color is light brown, and the finer grades of underhair are soft and silky. The fine body hairs are about 1 in. long, and are downy, but the beard hairs are coarse, strong and tough. Beard hairs are up to 4 in. in length, and are the ones used for brushes. The color is a natural tan; the white hairs sell at a discount. The best hair is from the Bactrian animals.

**Camphor.** The peculiar white resin of the *Cinnamomum camphora*, an evergreen tree with laurellike leaves, and reaching a height of 100 ft. Camphor is used in celluloid manufacture, disinfectants, and in explosives, and the oils of camphor are used as turpentine substitutes. More than 80 per cent of the camphor production is employed for celluloid, 15 per cent for disinfectants, and the remainder for a great variety of uses. The tree occurs naturally in China and southern Japan. Formosa is the center of the industry. Camphor, $C_{10}H_{16}O$, is contained in all parts of the tree, but in Formosa it is distilled almost exclusively from the wood of the trunks, roots, and large branches. Steam or water distillation is employed, and from 20 to 40 lb. of chips produce 1 lb. of camphor. The crude camphor is refined principally in Kobe, and the crystallized "flowers of camphor" is pressed to remove the oil. Camphor has a specific gravity of 0.986 to 0.996, and melts at 175°C. The red, or raw, camphor oil is fractionated into white and brown Camphor oil, the first of which is used as a turpentine substitute, the brown oil going into cheap perfumery making. Synthetic camphor is derived from turpentine, borneol, or other substances by complex processes. Commercial synthetic camphor is optically inactive, and usually contains some impurities. It has the same uses as camphor.

A noninflammable substitute for camphor, produced by the Celluloid Corporation under the name of Lindol, is Tricresyl phosphate, formed from a combination of cresylic acid and phosphoric acid. It is a colorless, odorless, viscous liquid which solidifies at −20°C. and decomposes at 300°C. The specific gravity is 1.176. It is insoluble in water. See Borneol.

**Camwood.** The wood of the tree *Baphia nitida*, native to West Africa. The wood has been used in England for machine bearings, and will withstand bearing pressures up to 8,000 lb. per sq. in. It is also used for tool handles. It is exceedingly hard and has a coarse, dense grain. The weight is about 65 lb. per cu. ft. This wood is sometimes confused with Barwood, from the tree *Pterocarpus santalinus*, of West Africa, employed for the same purposes and as a dyewood. Camwood is also a dyewood, and has a reddish-brown color. Both woods contain a red coloring matter known as Santalin.

**Canada balsam.** Also called Balm of Gilead. A yellowish, viscous liquid of pleasant odor and bitter taste, obtained from the pine tree *Abies balsamea*, of Northeastern states and Canada. It is a class of turpentine, and is used as a solvent for paints and in polishes and leather dressings. When distilled it yields turpentine and rosin.

**Canaigre.** An important leather tanning material extracted from the roots of the low-growing plant *Rumex hymenosepalus*, growing wild in northern Mexico, and in the arid Southwest of the United States. The plant is known locally as Sour dock, and the roots contain 48 to 50 per cent of tannin. Canaigre was the tanning agent of the semicivilized Indians of ancient Mexico. See Tanning materials.

**Canary whitewood.** Also called Whitewood, or Tulipwood. The wood of the tree *Liriodendron tulipifera*, of the Eastern United States and Canada. The tree has large, tuliplike flowers. The wood is widely known as Yellow poplar, and is used for carpentry, and for articles where a close, even grain is desired. Due to its close texture and even coefficient of expansion, it is used for expansion blocks in humidity regulators and testers. The wood is yellowish, is soft, and weighs about 30 lb. per cu. ft.

**Candelilla wax.** A yellowish wax obtained from the candelilla plant by boiling in water and skimming off the wax. The plant grows abundantly in northern Mexico and Southwestern United States. The specific gravity of the wax is 0.983 and the melting point is 67°C. It is used for varnishes,

polishes, leather finishes, and as a substitute for carnauba wax, or to adulterate carnauba or beeswax.

**Candle-nut oil.** An oil obtained from the kernels of the fruit of the *Aleurites moluccana*, a tree found in Oceania, the West Indies, and South America. The oil is variously known as Kukui, Kekune, Walnut, Lumbang, and Artists' oil, and is used as a drying oil for paints. The specific gravity is 0.923, and the iodine value is about 185. The fruit resembles the walnut but has a thicker shell. The kernels contain up to 70 per cent of oil, which is extracted by pressing.

**Cannel coal.** A variety of coal differing from ordinary coal in properties and composition. It is close and compact in texture, dull black in color, and breaks along joints, often appearing like black shale. It burns with a long, luminous, smoky flame, from which characteristic it derives its old English name, meaning candle. On distillation cannel coal yields a large proportion of highly illuminating gas, up to 16,000 cu. ft. per ton, leaving a residue consisting mostly of ash. At low temperature it yields a high percentage of tar oils. The proportion of volatile matter may be as high as 70 per cent. Cannel coal consists of coaly matter intimately mixed with clay or shale, often containing fossil fishes. It is supposed to have been derived from vegetable matter in lakes. It is found in Great Britain, and in the United States in Kentucky, Ohio, and Indiana. It is chiefly valued for its quick-firing qualities. Cannel coal from Scotland was originally called Parrot coal. Boghead coal is the name of a variety of streaky cannel coal of Scotland.

**Canvas.** A general name for a dense, heavy cloth of plain weave used for sails, sacking, packing, tents, and where strength and durability are required. It was formerly made of hemp or unbleached flax, but is now made of cotton. Canvas may be of many grades and qualities of fine to coarse yarns and weaves, and it may be soft finished or highly sized. See also Duck.

**Carbon.** The most widely diffused of all elements. It occurs in many combinations and in many different forms. It is colorless and transparent as in the diamond, opaque and black in graphite,

porous and velvety as in charcoal. It enters largely into coal, and is present in combination in gases, minerals, and organic materials. The symbol is C. The specific gravity is from 1.9 to 3.52. Amorphous carbon is not soluble in any known solvent. It is infusible and is chemically inactive at ordinary temperatures. At high temperatures it burns and absorbs oxygen. It has the property of dissolving in some molten metals, notably iron, and exerting great influence upon them. Cast iron, with graphitic carbon, and steel, with combined carbon, are examples of this. The carbon atom has the peculiar property of forming "ring" compounds, and there are more compounds of carbon than of all other known elements. Carbon enters into all organic material, and has the widest use of any element. "Carbon" brushes and electrodes are made of carbon in the form of graphite, petroleum coke, lampblack, or other materials, sometimes mixed with copper powder to increase the conductivity, and then pressed into blocks and baked. Activated carbon is amorphous carbon so prepared that it is very porous, giving increased exposed area. It is used for removing color, odors, or unwanted flavors from liquids by adsorption. Commercial activated carbons have the form of finely divided black powders. Nuchar is an activated carbon of the West Virginia Pulp & Paper Company. See also Graphite, Diamond, Charcoal, Lampblack.

**Carbon bisulphide.** A liquid of the composition $CS_2$, made by heating together carbon and sulphur. It is inflammable and poisonous and dangerous to handle, but is a valuable solvent for oils, fats, waxes, and resins. It has a specific gravity of 1.263, boiling point of 46°C., and solidifying point of −113°C. The liquid is highly refractive, and has a characteristic smell.

**Carbon black.** The carbon resulting from the incomplete combustion of a gas, usually deposited by contact of the flame on a metallic surface, but also made by the incomplete combustion of the gas in a chamber. The carbon black deposited by the first method is called Channel black, taking the name from the channel iron used as the depositing surface. The carbon black made by other processes is called Soft black and is weaker in color strength. It is therefore not used for pigment. Carbon black

from artificial gas is a very glossy product with an intense color. All of the commercial product is from natural gas. Thermotomic black, a grade made by the thermal decomposition of the gas in the absence of oxygen, is used as a filler in rubber and does not retard the vulcanization like ordinary carbon black. Carbon black is used as a paint pigment, in stove polishes, carbon paper, and printing and drawing inks. Its larger use is in rubber for automotive tires to give added wearing qualities to the tire. It is produced largely in Louisiana, Texas, and Oklahoma. The yield per thousand cubic feet of gas is from 1.1 to 1.8 lb. See also Vine black.

**Carbon dioxide.** Also called carbonic acid, and in its solid state, Dry ice. A colorless, odorless gas of the composition $CO_2$, which liquefies at −65°C. and solidifies at −78.2°C. It is obtained as a by-product of distilleries, from burning lime, and from gas wells. In liquid form it is marketed in cylinders, and is used in fire extinguishers, spray painting, refrigeration, inert atmospheres, and in many industrial processes. See also Cardox. Dry ice is a white snowlike solid used for refrigeration, and is sometimes used for shrinking and cold-treating metals. Flakice, used for packing products to be transported cold, is not a dry ice but is thin broken curved sheets of water ice made by freezing on a metal refrigerator cylinder and automatically stripping off the ice.

**Carbonite.** A natural coke found in England and in Virginia. It is a cokelike mineral formed by the baking action of igneous rocks on seams of bituminous coal. It is used as a coke. The name is also used as a trade name for an activated charcoal made from a mixture of finely ground anthracite, pitch, and sulphur. Carbonite is also a trade name of the General Abrasive Company, Inc., for a silicon carbide abrasive.

**Carbon paper.** Paper used for duplicating pen, pencil, or typewriting. It is made by coating the paper with a mixture of a pigment and a medium. The pigments used include carbon black, Prussian blue, organic red, and blue and green lakes. The medium is composed of mixtures of waxes and oils chosen to give

a composition of the desired consistency and melting point. The waxes and oils may be carnauba wax, paraffin, castor oil, oleic acid, stearic acid, or pitch. Paper of a special texture must be used; rag papers are considered the best.

**Carbon steel.** Any steel owing its distinctive properties to carbon chemically combined with the iron. If other elements in influencing proportions are in the steel, the latter is designated as an alloy steel, except that up to 1.65 per cent of manganese, 0.60 silicon, and 0.60 copper, may be included without the steel being considered as alloyed. Likewise, small amounts of sulphur to give free machining properties may be added without changing the name. When the carbon is below 0.15 per cent, the metal is usually called iron; when the carbon exceeds 0.60, the steel is usually considered to be tool steel. However, there is no fixed dividing line, and carbon steels for general use may be high or low in carbon. Rail steel, for railway rails, is characterized by the fact that the carbon increases with the weight of the rail. A.R.E.A. standards call for 0.50 to 0.63 carbon and 0.60 manganese in a 60-lb. rail; a 140-lb. rail has 0.69 to 0.82 carbon and 0.70 to 1.0 manganese.

Carbon steels have a wide range of use for construction, machinery, and tool parts. See Machinery steel and Cold-rolled steel. But straight carbon steel has low strength compared with alloyed steels, and is now largely replaced by steels having high manganese, or small percentages of chromium, vanadium, and other elements. The average tensile strength of a cold-rolled or drawn carbon steel with 0.15 to 0.25 per cent of carbon, S.A.E. 1020, is from 40,000 to 60,000 lb. per sq. in., with an elongation of 30 to 40 per cent; one having 0.50 to 0.60 per cent may have a strength of 120,000 lb. per sq. in. These steels are tough and are easy to machine, but they will not withstand repeated shocks and stresses. The steels with very low carbon are ductile and are useful for deep drawing. Screw stocks, or Free-cutting steels, contain up to 0.045 phosphorus and up to 0.15 sulphur, and are produced regularly in the carbon ranges from 0.08 to 0.25, designated as S.A.E. 1112 to S.A.E. 1120. See also Tool steel, Alloy steel, Iron, Steel.

**Carbon tetrachloride.** A heavy, colorless liquid of the composition $CCl_4$, which is an important solvent for fats, asphalt, rubber, bitumens, and many gums. It is notable as a noninflammable solvent for materials sold in solution, but is more expensive than the aromatic solvents and is toxic. It is widely used as a degreasing and cleansing agent in the textile industries. It was discovered in 1839, and first used in Germany as a grease remover under the name of Katharin. It is now employed in such cleansing compounds as Carbona, and as a component of chemical fire extinguishers such as Pyrene. It is also used as a disinfectant, and because of its high dielectric strength has been employed in transformers. Carbon tetrachloride is obtained by the chlorination of carbon bisulphide. The specific gravity is 1.584, boiling point 77°C., and solidifying point −23°C. Carbon tetrachloride is one of a group of chlorinated hydrocarbons.

**Carnauba wax.** An exudation from the fanlike leaves of the palm tree *Copernica cerifera*, of Brazil. The trees grow up to 40 ft. in height with leaves 3 ft. in length. The wax forms in flakes on the outside of the leaves and is melted into cakes. The wax comes in hard, vitreous, yellowish cakes or lumps that melt at about 85°C. and have a specific gravity of 0.995. It is soluble in alcohol and in alkalies. Carnauba wax is used in varnishes, floor polishes, leather dressings, and for blending with beeswax. It increases the hardness of beeswax or paraffin. Burnishing wax, in the shoe industry, is carnauba wax either pure or blended with other waxes. The blended waxes are softer.

**Carnotite.** A mineral found in Utah and Colorado and employed as a source of radium, uranium, and vanadium. It is a vanadiate of uranium and potassium, $V_2O_5 \cdot 2UO_3 \cdot KO \cdot 3H_2O$. It is found with other sands and gives them a pale yellow color. Carnotite ores may contain 2 to 5 per cent of uranium oxide and up to 6 per cent of vanadium oxide, but the ore usually runs 2 per cent of $V_2O_5$. For the production of vanadium oxide the ore is roasted with salt, leached, and the oxide precipitated with acids and sintered. The production of radium from the ore is a complex process; 400 tons of carnotite sand are required for the production of a gram of radium.

**Cartridge brass.** One of the standard alloys of the brass mills, containing 70 per cent of copper and 30 zinc. Because of the general use of the alloy for deep drawing the highest grade of zinc is used and all lead is excluded. It has high ductility and is used for deep drawing, spinning, and for such articles as horns and cornets. It brazes well and electroplates easily. Rolled sheet has a tensile strength of 85,000 lb. per sq. in. when hard, and 45,000 when annealed. The elongation is 10 to 50 per cent. The coefficient of expansion is 0.0000103 per deg. F., weight 0.308 lb. per cu. in., and electrical conductivity 25 per cent that of copper. A somewhat more ductile alloy, used for wire goods, is Eyelet brass, containing 68 per cent of copper and 32 zinc. A grade produced by the American Brass Company under the name of Spinning brass contains 67 per cent of copper and 33 zinc. Lubaloy, of the Western Cartridge Company, contains some tin. Primer brass, for cartridge primers, may be the 70–30 cartridge brass, or it may be a higher copper alloy. See Gilding metal.

**Casehardening materials.** Any material employed for adding carbon to the outside of low-carbon steels or to iron so that upon quenching a hardened case is obtained, the center of the steel remaining soft and ductile. Commercial mixtures for this purpose are called Carburizing compounds. The usual solid material is charcoal made from bone or wood. It is obtained in "compound" form mixed with barium carbonate, charred leather, coal, or coke. The articles to be carburized for casehardening are packed in the compound in metallic boxes for heating in the furnace. A common mixture is 60 per cent charcoal and 40 barium carbonate. The latter decomposes giving carbon dioxide which is reduced to carbon monoxide by the carbon under the heat. If charcoal is used alone, it is slow and the action is spotty. Leather and bone charcoals are rapid in action. Coal and coke are slow in action. Salt is sometimes added to aid the carburizing action. By proper selection of the compound the carbon content may be varied in the steel from 0.80 to 1.20 per cent. The carburizing temperature for carbon steels is 1600°F., and for alloy steels about 1525°F. Two to six hours are required, depending upon the depth of case required. The principal liquid carburizing material

is sodium cyanide, which is melted in a pot and the articles dipped in, or rubbed on the red-hot steel. Gases rich in carbon, such as methane, may also be used for carburizing, by passing the gas through the box in the furnace. When ammonia gas is used to impart nitrogen to the steel, the process is not called casehardening but is referred to as nitriding. Casehardening compounds are marketed under a wide variety of trade names, and many have a base of hardwood charcoal or of charred bone, with sodium carbonate, barium carbonate, or calcium carbonate. Char, of the Char Products Company, is a carburizing material in which the particles of coal-tar carbon are surrounded by an activator and covered with a carbon shell. Casehardening by packing in compounds, is called "pack-hardening." Cyanide hardening gives an extremely hard, but superficial case. Nitrogen as well as carbon is added to the steel by this process. It is valued for instruments. See Potassium cyanide.

**Casein.** A whitish to yellowish granular or lumpy material precipitated from milk by the action of acids or rennet. It is produced as a by-product of the butter and cheese industries. Cows' milk contains about 3 per cent of casein, and Argentina is the largest producer and exporter of the material. Casein is insoluble in water or in alcohol, but is attacked by alkalies. It is employed in making molding plastics, glazing for paper, glues, leather dressings, and polishes.

**Casein plastics.** A group of substances made usually by the action of formaldehyde on casein, and used for molding buttons, buckles, and novelties. The process was invented in 1885, but is now varied by the addition of salts to prevent the resin from becoming rubbery, or by the extraction of albumen and natural salts. Casein plastics can be molded under heat and pressure. They are thermoplastic and can be machined easily. They are noninflammable and are good electrical insulators. They can be dyed to very light shades. The specific gravity is about 1.35, and the tensile strength 7,500 lb. per sq. in. They are not hard and are not usually employed for mechanical parts. Casein plastics are marketed under many trade names. Some of these are Aladdinite, of the Aladdinite Company, Inc.; Inda, of the American Machine

& Foundry Company; Erinoid, of the Erinoid Company of America; Lactoid, of the British Xylonite Company, Ltd.; Lactonite, of the British Lactonite Company; Ameroid, of the American Plastics Corporation; Sicalite, of the Société Nobel Française; Karolith, of the Karolith Corporation; and Galalith, of the International Galalith Company. Casein fiber is an extruded casein product used for weaving fabrics. The fiber is superior to wool in certain qualities, notably in that it is not attacked by moths, but is inferior in general qualities. Lanitol is the trade name of a patented casein fiber.

**Cashmere.** A fine, soft, silky fabric made from the hair of the Cashmere goat raised on the slopes of the Himalaya Mountains of Asia. The hair is obtained by combing the animals, not shearing, and the production is small. The hair is straight and silky, but not lustrous, and is difficult to dye. The fabrics are noted for warmth, and the production goes mostly into shawls or fine ornamental garments. See also cotton cashmere.

**Cassiterite.** Also called Tin stone. It is the only commercial ore of tin, and is a Tin dioxide, $SnO_2$, containing 78.6 per cent of tin. It usually occurs massive granular with a specific gravity of 6.8 to 7.1, and a hardness of 6 to 7. The color is usually brown or black with a dull luster. Cassiterite is a widely distributed mineral, but is found on a commercial scale in only a few localities. It is worked in Cornwall, England, in Bolivia, Malay Straits, and in parts of Australia. The mineral cassiterite is present in the ore usually in amounts of from 1 to 5 per cent. It occurs in veins, called Lode tin, and in placer deposits. Lode tin is first crushed and then concentrated by gravity. It is roasted to eliminate sulphur and arsenic. The concentrates average 65 to 70 per cent. The smelting is done usually in reverberatory furnaces. See also Tin.

**Cast iron.** A combination of pure iron with from 2 to 6 per cent of carbon, receiving its name from the fact that it is readily cast into almost any desired shape. The A.S.T.M. definition is "Iron containing so much carbon that it is not malleable at any temperature." This limit is about 1.7 per cent. Cast iron is of

two kinds, white cast iron and gray cast iron. The first is a chemical compound of iron with the carbon; the second contains most of the carbon in the state of graphite mechanically mixed with the iron. Cast iron is brittle and not malleable. Its advantages are that it is easy to give it any desirable form in the casting, is easy to machine, is cheap, and has a higher proportional fatigue strength than steel. It is used for the intricate and massive parts of machinery. White iron is made by chilling gray cast iron, and may be converted into gray iron by heating to 1850°F. for several hours. Nickel, chromium, and other metals are sometimes added to cast iron while molten to give additional strength, toughness, or hardness, but the iron is then generally known as Alloy cast iron. See Nickel cast iron.

Cast iron is made by melting pig iron in a cupola in contact with the fuel, which is usually coke. The pouring temperature is about 2460°F. With an electric furnace, scrap iron may be employed alone without pig, and the furnace may be operated continuously. The combined carbon governs the melting point. An iron with 4.2 per cent combined carbon and 0.2 graphite melts at 1990°F., while one with 0.17 combined carbon and 3.57 graphite melts at 2260°F. If the combined carbon is above 0.75 per cent, machining is difficult. At 1.50 per cent machining is impossible with ordinary tools. At 1.75 per cent the hardness may be as high as 477 Brinell, whereas soft iron is as low as 88 Brinell. Pure iron can take up to 4.6 per cent of carbon. Manganese and chromium increase this saturation point, but silicon reduces it.

The combined carbon is known as Austenite, and the iron-carbon compound $Fe_3C$, which forms when some of the austenite changes on cooling, is called Cementite. The term Ferrite is used for the iron crystals having no carbon. Pearlite, the most desirable structure of cast iron, consists of alternate layers of ferrite and cementite. The tensile strength of iron with such a structure if it could be obtained throughout would be 100,000 lb. per sq. in. See High-test cast iron. Gun iron, formerly used for casting cannon, is a fine-grained iron of uniform texture, low in sulphur and in total carbon, made in the air furnace. Graphite is a weakening element in cast iron. The lower the total carbon the

stronger the cast iron. To obtain this result steel scrap is mixed in. See Semisteel.

Phosphorus in cast iron increases fluidity, but above 0.6 per cent makes the iron hard. Sulphur is an undesirable impurity. Silicon goes into solid solution in iron to form iron silicides and precipitates graphite. Small amounts make the cast iron soft, but large quantities make it glassy hard. See Silicon iron. Copper is also used as a graphitizer, up to 3 per cent being used. Engine cylinder blocks of high heat conductivity and strength contain about 0.75 per cent copper. Manganese decreases the magnetic properties of cast iron. Nomag, an English nonmagnetic cast iron, contains 6 per cent of manganese. Adding nickel makes this manganese iron machinable without changing its nonmagnetic quality. Small amounts of tungsten producing Tungsten cast iron, with 1 to 2 per cent of tungsten, increase the tensile and transverse strengths of cast iron, but reduce its hardness. A standard gray iron having a tensile strength of 26,000 lb. per sq. in., is increased to about 40,000 lb. per sq. in. by the addition of 1.2 per cent of tungsten.

The specific gravity of gray cast iron is 7.10, and of white iron 7.50. The coefficient of expansion is 0.0000056. Tensile strengths vary from 18,000 to 25,000 lb. per sq. in. for ordinary gray iron. Compressive strengths vary from 60,000 to 200,000 lb. per sq. in. Ordinary cast iron contains 3.25 to 3.75 per cent carbon, about 2.5 silicon, 0.60 manganese, 0.06 sulphur, and 0.40 to 0.80 phosphorus. Cast iron is an excellent metal for parts having "quiescent" loads, such as machine frames. The dead-load factor of safety is 4, but for varying loads and shocks it is 15. Iron castings should be seasoned before machining, or else annealed by heating and cooling slowly. Casehardening is done by using powdered ferromanganese on the mold surface. Synthetic cast iron is made from steel scrap and turnings melted together with carbon in the electric furnace.

Cast irons made by special processes, or with alloying elements, are sometimes marketed under trade names. Pomoloy is the trade name of the Pomona Pump Company for an unalloyed cast iron with a tensile strength of 40,000 lb. per sq. in. and hardness of 215 Brinell. DeLavaud metal is a trade name of the U.S.

Cast Iron Pipe and Foundry Company for iron cast into pipe by a centrifugal process in rotating steel molds which, after annealing, produces a pipe with an outer layer of malleable iron, a middle layer resembling steel, and an inner surface of gray iron. Hi-Tem iron is the name given by the Bethlehem Foundry and Machine Company, to corrosion-resistant iron used in processing vessels. Hi-Tem S is a high-manganese iron used for retorts. See also Malleable iron.

**Castor oil.** An oil obtained by expression from the seed beans of the castor plant, *Ricinus communis*, which grows wild, and is also extensively cultivated in nearly all tropical and subtropical countries. It is used for mixing with other oils for cutting compounds and for some lubricating oils. An important use is for waterproofing leather and as a filler to give greater elasticity and permanency to the leather. Mixed with diacetone alcohol castor oil is used in hydraulic brake cylinders. It is also converted into blown oils. Another commercial use is as a medium in gums and in such things as carbon paper pigments. It increases the lathering power and the solubility in cold water of soaps. It has high specific gravity and viscosity, has excellent keeping qualities, and does not "dry" on exposure. It is sometimes used for lubricating heavy machinery. Castordag is a solution of 10 per cent of colloidal graphite in castor oil used as a lubricant for high-temperature conditions. It is a product of the Acheson Colloids Corporation. The castor-oil seeds have the appearance of mottled colored beans, and are enclosed in hard husks which are removed before crushing. The beans contain about 50 per cent of oil. The oil obtained from the first cold pressing is used largely in medicine. The inferior grades from the second and third hot pressing are the commercial lubricating oils. The residue cake is poisonous and is used only as a fertilizer. Castor oil when pure is colorless and transparent. It has a characteristic acrid, unpleasant taste. The iodine value is 82 to 90, and the saponification value is 147. The specific gravity is about 0.965. It is soluble in alcohol.

**Cast steel.** Steel that has been cast into sand molds to form finished or semifinished machine parts or other articles Steel

castings are used to replace forgings where only small quantities are required that would not justify the cost of forging dies, and for large parts. Cast steel is stronger and tougher than malleable iron and, when heat-treated, will have a tensile strength above 70,000 lb. per sq. in. Standard medium-carbon cast steel of the Michigan Steel Casting Company has a tensile strength of 80,000 lb. per sq. in., and elongation 15 to 20 per cent. Federal Specifications for carbon cast steel call for 0.35 per cent carbon in the soft grade, 0.45 in the medium grade, and 0.50 in the hard grade. The tensile strength of the soft is 60,000 lb. per sq. in., and of the hard 80,000 lb. per sq. in. The yield point is taken as 45 per cent of the tensile strength. British Engineering Standard specifications call for cast steel for general purposes to have 0.30 per cent carbon, and have a tensile strength of 26 tons per sq. in., with elongation 15 to 20 per cent. The carbon content of cast steel is not usually over 0.45 per cent, and the manganese is usually 0.60 to 0.80 per cent. Nickel, chromium, or a high percentage of manganese may be added to make special alloy castings; the term cast steel generally refers only to plain carbon steels. The shrinkage allowed for cast steel is ¼ in. per ft. Cast steel has the disadvantage in comparison with forged steel that it may contain blow holes, slag, sand holes, shrinkage cavities, or cold shuts, the last from pouring at too low a temperature.

Alloy steels for heavy-duty castings may be chromium, with 0.80 to 1.10 per cent of chromium; vanadium, with 0.15 to 0.20 per cent vanadium; chrome-vanadium; 3½ per cent nickel; nickel-chromium; or manganese, with either high or low manganese content. One of the simplest alloy cast steels for parts subject to shock and fatigue stresses is the standard low-carbon and medium-carbon steel with 2 per cent of nickel. It is used for mining and other heavy machinery, locomotive frames, and ship castings. The tensile strength is up to 85,000 lb. per sq. in., with yield point up to 55,000 lb. per sq. in., and elongation 25 to 32 per cent. The nickel, with manganese up to 0.90 per cent, gives the steel greater shock resistance at low temperatures, as ordinary steel is brittle in cold climates or when used on refrigerating equipment. A 3 to 3.5 per cent nickel steel used for cast gears for rolling mills has a tensile strength of 110,000 lb. per sq. in.,

elongation of 20 per cent, and hardness of 200 Brinell as cast. A nickel-chromium-molybdenum cast steel for heavy gears contains 1.5 per cent nickel, 0.75 chromium, 0.35 molybdenum, 0.68 manganese, and 0.35 carbon. The tensile strength is 145,000 to 160,000 lb. per sq. in. Small amounts of aluminum are added to cast steel just before pouring to "degasify" and produce homogeneous castings. Alloy cast steels are marketed by many companies under a variety of trade names such as Tigerloy of the Massillon Steel Casting Company.

**Catalyst.** A material used to cause or accelerate chemical action without entering into the chemical combination. Various metals, especially platinum and nickel, are used to catalyze or promote chemical action in the manufacture of synthetics. Acids may be used to aid in the polymerization of synthetic resins. Mineral soaps are used to speed up the oxidation of vegetable oils. Cobalt oxide is used for the oxidation of ammonia. Cobalt and thorium are used for synthesizing gasoline from coal. Many other materials may be used.

**Catechu.** An extract obtained from the heartwood and from the seed pods of the tree *Acacia catechu*, of Japan and southern Asia. It is used in tanning leather, and also as a dyestuff, giving a brown color. The name is also sometimes erroneously applied to gambier, which also contains catechu tannin, $C_{15}H_9(OH)_5$. Catechu, or Cutch, comes either as a liquid which is a water solution, or as brownish, brittle, glossy cakes. The extract contains 25 per cent of tannin, and the solid 50 per cent. It is a powerful astringent. When used alone as a tanning agent, the leather is not of high quality, being of a dark color, spongy, and water absorbent. Burma cutch is from *A. catechuoides*. Indian cutch is from *A. sundra*. The latter is frequently adulterated with starch, sand, or other materials. Wattle is an extract from Australian or east African acacia. See also Mangrove cutch.

**Catgut.** String made from the intestines of sheep, used chiefly for violin strings, but also for tough, durable cords for making racquets and other articles. After cleansing and soaking in an alkali solution, the intestines are split, drawn through

holes in a plate, cured in sulphur or other substance, and graded according to size.

**Cedar.** A general name which includes a great variety of woods. The true cedars comprise trees of the natural order *Coniferae*, genus *Cedrus*, of which there are three species: Lebanon cedar, *Cedrus libani;* Himalayan cedar, *C. deodora;* and Atlas cedar, *C. atlantica*. The differences are slight, and all of the species are sometimes classed as *C. libani*. All are mountain trees, and are native to Europe, Asia, and Africa. Cedar is yellow in color, takes a beautiful polish, and is very durable. It is also very fragrant. It is used in construction work, and timbers in temples in India more than 400 years old are still in perfect preservation. The wood weighs about 36 lb. per cu. ft. Numerous species of *Cedrela* occur in tropical America, Asia, and Africa, and are also commonly called cedar, but the wood resembles mahogany. See Spanish Cedar. In the United States and Canada the name cedar is applied to woods of species of *Thuja*, *Juniperus*, and *Cupressus*. See Yellow cedar, Western red cedar, Port Orford cedar, and Eastern red cedar.

**Celluloid.** A molding material consisting of cellulose nitrate treated with camphor to reduce its inflammability and make it more plastic. It was invented in 1868 by J. W. and J. S. Hyatt, and was an improvement on the Parkesine produced in England in 1855 by Alexander Parkes, which consisted of nitrocellulose with camphor and castor oil. It is now made from nitrated cotton, the proportion of nitrogen being from 9.5 to 11 per cent, and the compound is not detonated by a blow. See Nitrocellulose. It usually contains 30 to 40 parts of camphor for 100 parts of nitrocellulose. Methyl or amyl alcohols are the usual solvents, and plasticizers such as tricresyl phosphate are used. The pigment is added during the incorporating of the camphor, or dyes are applied externally. Celluloid is a transparent mass, molding easily at 100°C. It is highly elastic, and has high tensile strength. It is insoluble in water, but is soluble in alcohol, and is decomposed by various acids. It can be cemented with dichlorohydrin. At 145°C. it begins to decompose, and when ignited it burns with a smoky flame. The fumes are ex-

tremely poisonous and affect the heart. Stannous chloride, or some other substance, is sometimes employed in celluloid to make it "uninflammable." Modified celluloids, without camphor, are made by substituting methyl-acetanilide or other chemicals. Ordinary celluloid weighs about 0.050 lb. per cu. in. The trade name Celluloid is owned by the Celluloid Corporation.

**Cellulose.** The main constituent part of plants, which, when extracted, is employed for making paper, and in many combinations such as nitrocellulose. Chemically, cellulose is made up of long-chain molecules in which the complex unit $C_6H_{10}O_5$ is repeated many times. The simplest form of cellulose used industrially is Regenerated cellulose, in which the chemical composition of the finished product is similar to that of the original cellulose. Regenerated cellulose is made from wood or cotton pulp digested in a caustic solution to which carbon bisulphide is added to disintegrate the fibers. The viscous liquid is forced through a slit into an acid bath to form a thin sheet, which is then purified and bleached. Cellophane, of the duPont Cellophane Company, Inc., is a regenerated cellulose used in the form of thin sheets for wrapping. It is dyed in colors or embossed, or used plain. The thinnest sheets, 0.00088 in. in thickness, have 21,500 sq. in. per lb. The waterproofed material is coated with a thin film of cellulose nitrate lacquer. Ethyl cellulose is a colorless, odorless ester of cellulose resulting from the reaction of ethyl chloride and alkali cellulose, used for coatings, plastics, and as a hardening agent in resins and waxes. The specific gravity is 1.14. It is very flexible and stable to light, and forms durable, alkali-resistant coatings for paper. Ethocel is the name of ethyl cellulose of the Dow Chemical Company. Methyl cellulose is a white, granular, flaky material which is a strong emulsifying agent, and is used in soaps, floor waxes, shoe cleaners, and in emulsions of fats and waxes. It dissolves in cold water; in soaps it lowers the surface tension of the water and aids lathering.

**Cellulose acetate.** An amber-colored, transparent mass, of the composition $C_6H_5(CO_2CH_3)_5$, employed as a molding compound, and for making artificial silk, or "rayon," and for photographic films and lacquers. It is made by the acetylization of

cellulose with acetic acid. Unlike nitrocellulose, or pyroxylin, it is not inflammable, and also does not discolor like pyroxylin. For this latter reason and because of its lighter color it is preferred to pyroxylin for making nonshatterable glass. A sheet ⅛ in. thick will transmit 90 per cent of the light. As a plastic molding material it can be formed in molds at 2,000 lb. per sq. in. pressure to any desired shape. The parts can be machined easily, are tough and not brittle. The molding material is used for making electrical parts, buttons, handles, and other articles. It has high dielectric strength, but will not withstand temperatures above 160°C. It is insoluble in water or oils and has been used for drying rolls in paper-mill machines, and for gears. It is soluble in alcohol, and the cellulose-acetate lacquers are solutions in alcohols or other organic solvents. They are quick drying and can be made to any color with suitable pigments. They are used for automobile finishes and for ornamental painting. A cellulose-acetate molding material marketed by the Tennessee Eastman Corporation under the name of Tenite has a specific gravity of 1.27 to 1.37, tensile strength of 4,300 to 5,000 lb. per sq. in., compressive strength of 12,000 to 16,000 lb. per sq. in., and dielectric strength of 700 to 800 volts per mil. Cellomold is a cellulose-acetate molding material of F. A. Hughes & Company, Ltd. Lumarith is a cellulose-caetate thermoplastic marketed by the Celluloid Corporation in rods, sheets, tubes, and molding powder. Masuron, of John W. Masury & Son, is a cellulose-acetate molding resin in powder and slab form. Nixonite, of the Nixon Nitration Works; and Fibestos, of the Fiberloid Corporation, are cellulose-acetate molding materials. Protectoid is Lumarith in the form of noninflammable motion-picture film. Acele is the trade name of E. I. duPont de Nemours & Company, Inc., for yarns of cellulose acetate. Plastacele is the trade name of the same company for cellulose-acetate plastics and molding powders. Kodapak is a cellulose-acetate transparent sheet material produced by the Eastman Kodak Company for packaging.

**Cement.** A substance, generally in powdered form, that can be made into a paste usually by the addition of water, and when molded will set into a solid mass. Cements are extensively used

for building construction, the best known being portland cement for making concrete. See Portland cement, Roman cement, Keene's cement, Gypsum. Natural cements are produced by the burning of sandy limestones and grinding the product. They are inferior to portland cement, and under the name of Masonry cement are used as mortar for laying brick and stone. Various trade names are also given to these cements. Oxychloride cement is composed of magnesium chloride and calcined magnesia. It is used for floors and stucco. Numerous organic and inorganic compounds used for fastening together, or "cementing," materials are called cements. These include glues, and also mixtures of rubber or gums which have been dissolved in solvents and compounded with resins. See Adhesives.

**Cement mortar.** A mixture of portland cement, sand, and water. Cement mortar is much harder and more durable than lime mortars, but some lime is often added to make it spread more readily. The proportion of sand is not greater than 3 to 1 of cement. A mortar composed of 1 part of portland cement to 3 parts of sand will have a compressive strength after 1 day of 800 lb. per sq. in.; after 7 days, 2,750 lb. per sq. in.; and after 28 days, 3,100 lb. per sq. in. Cement mortar is more costly than common mortar, but is useful in masonry exposed to water, or where great strength is required. It is also employed as a finish covering for walls of masonry, brick, or concrete. A 2½-to-1 cement mortar weighs about 135 lb. per cu. ft. See also Portland cement and Concrete.

**Cerargyrite.** An ore of the metal silver, found in the upper zone of silver veins. It occurs in Nevada, Colorado, Idaho, and in Peru, Chile, and Mexico. It is sometimes called Horn silver due to its hornlike appearance. It is a silver chloride, AgCl, containing theoretically 75.3 per cent of silver, with sometimes some mercury. The hardness is 2.3 and specific gravity is 5.8. It is usually massive, resembling wax, with a pearl-gray color.

**Cerium.** A metallic element, symbol Ce, belonging to the group of Rare-earth metals, or Rare earths, to which Praseodymium and Neodymium also belong. See table of elements.

Didymium is a mixture of neodymium and praseodymium, used to give glass a neutral gray color. The rare earths are not rare but are difficult to separate out. Cerium is not used alone but has a variety of uses in its compounds. Cerium has an iron-gray color, is only slightly harder than lead, and is malleable. It melts at 623°C. The specific gravity is 6.92. The chief source of cerium is monazite sand from Brazil, India, and the Carolinas. It was formerly a by-product of the incandescent mantle industry, left in the residue of the sand after the thorium oxide was removed. Monazite contains from 25 to 35 per cent of Cerium oxide, called Ceria, which is a pale-yellow heavy powder of specific gravity 7.65, and composition $CeO_2$ used in coloring ceramics. Ceric oxide, $Ce_2O_3$, with specific gravity of 7.3, and refractive index of 2.19, absorbs ultraviolet light and is the best opacifier for ceramics. It is also used in special glasses. Cerium nitrate, a red crystalline substance of the composition $Ce(NO_3)_3 \cdot 6H_2O$, is used in gas-mantle manufacture. The cerium mixed metal, known as misch metal, is employed with iron in making pyrophoric alloys. Cerium salts are used for dyes and in coloring glass. Ceric titanate gives a golden yellow color to ceramics, while Ceric molybdate gives a blue color. See Auer metal, and Misch metal.

**Chalk.** A fine-grained limestone, or soft, earthy form of Calcium carbonate, $CaCO_3$, composed of finely pulverized marine shells. It has a wide variety of industrial uses. Whiting and Paris white are names given to grades of chalk that have been ground and washed for use in paints, inks, and putty. High calcium marbles and limestones are the source of most of the American whiting. Chalk is employed in putty, crayons, paints, rubber goods, linoleum, calcimine, and as a mild abrasive in polishes. Chalk comes largely from the southern coast of England and the north of France. The color is white, gray, or yellowish, depending on the impurities. The specific gravity may be as low as 1.8. The commercial grades depend on the purity, color, and fineness. French chalk is a high grade of massive talc cut to shape and used for marking. Finely ground calcium carbonate is marketed under trade names as a rubber filler. See also Calcite.

**Chamois.** A soft, pliable leather originally made from the skins of the chamois, *Antilopa rupicapra*, a small deer inhabiting the mountains of Europe but now nearly extinct. The leather was of a light-tan color, with a soft nap. All commercial chamois is now made from the skins of lamb, sheep, goat, or from the thin portion of split hides. The original Artificial chamois was made by tanning with formaldehyde or alum, impregnating with oils, and subjecting to mechanical suèding, but chamois is also made by various special tannages with or without suèding. The Federal Trade Commission limits the use of the term to oil-dressed sheepskins mechanically suèded, but there are no technical precedents for this limitation although in the use of fish oils for tanning there is a combination of the oil with the skin protein which makes it distinctive. The leather will withstand soaking in hot water and will not harden on drying. It is used for polishing glass and plated metals. Buckskin, a similar pliable leather, but heavier and harder, was originally soft-tanned deerskin but is now more frequently made from goat skins.

**Charcoal.** An amorphous form of carbon, made by enclosing wood billets in a retort and exposing to a red heat for 4 or 5 hr. It is also made by covering large heaps of wood with earth, and permitting them to burn slowly for about a month. Wood charcoal is used as a fuel, for gunpowder, for carbonizing, and as an absorbent. Charcoal for gunpowder is made from alder, willow, or hazel wood. Absorbent charcoals are usually from coconut shells. See Activated charcoal. A cubic inch of boxwood charcoal will absorb 90 cu. in. of ammonia gas. Commercial wood charcoal is made with a yield of about 25 per cent of the weight of the wood, and is not pure carbon. The average composition is 95 per cent carbon and 3 per cent ash. It is an excellent fuel, burning with a glow at low temperatures, and with a pale blue flame at high temperatures. With an air blast it can be used for smelting iron. Red charcoal is wood charcoal made at a low temperature, and retaining much oxygen and hydrogen. Charcoal is also produced as a by-product in the distillation of wood, a retort charge of 10 cords of wood yielding an average of 2,650 gal. of pyroligneous liquor, 11,000 lb. of gas, and 6 tons of charcoal.

Tec-Char is the trade name of the Tennessee Eastman Corporation for graded granular by-product charcoal. Charklets is the name for biscuit-shaped briquettes of powdered charcoal put up with a binder and used for fuel. Animal charcoal is produced by heating bones or dried blood in a closed retort. It is used as a paint pigment or in decolorizing. Filt-char is a trade name for a bone charcoal used for filtering. See also Bone black. Charcolite is charcoal made from coal by a special process with calcium chloride. See Casehardening materials.

**Charcoal iron.** A type of pig iron made in the charcoal furnace. It has greater strength than ordinary foundry pig iron, and has a tendency to chill. It is employed for castings requiring strength and a hard outer surface, such as car wheels, and also for magnet cores. A standard composition is 3.5 per cent of total carbon, 0.70 of silicon, 0.40 of manganese, 0.50 of phosphorus, and 0.08 of sulphur. Cast iron made from charcoal iron has a denser structure than ordinary gray iron, and the specific gravity is as high as 7.80 compared with 7.10 for gray iron. Charcoal pig iron is also used for making a high-grade steel in special knobbling furnaces for use in the production of boiler tubes. Charcoal iron is marketed in various grades from 3.25 per cent graphitic carbon and 0.37 combined carbon, to 3.5 combined carbon. Elverite, of the Fuller Lehigh Company, is a charcoal type of cast iron, which gives a hard chill leaving a soft, gray-iron core. It is used for crushing mills. Swedelec is a Swedish charcoal puddled iron produced in a Lancashire hearth and rolled into a soft wrought-iron product. It is ductile and has high magnetic permeability and low hysteresis loss suitable for transformer cores. It is marketed by A. Milne Company. Swedish Lancashire iron has a fibrous structure, a tensile strength of about 40,000 lb. per sq. in., and elongation of 33 per cent. Stora is the trade name of Swedish charcoal iron in small notched pigs, used for making malleable iron.

**Chateauagy iron.** The low-phosphorus, copper-free pig iron produced from New York state magnetite ore. The original ore as mined contains about 28 per cent iron. The standard analysis of the pig iron is total carbon 4 per cent, silicon 0.75 to 4.0 per

cent, sulphur 0.03 maximum, phosphorus 0.03 maximum, manganese 0.10–0.15 per cent. Chateaugay iron is used for casting rolls, gears, cylinders, and machine parts.

**Cheesecloth.** A thin, coarse-woven cotton cloth of plain weave, 40 to 32 count, and of coarse yarns. It was originally made for wrapping cheese, but is now employed for wrapping, lining, interlining, filtering paints and enamels, and for polishing cloths. Cheesecloth is used for making strong, moisture-proof Baling paper by a process of coating the cloth with asphalt and pasting to one side of a heavy Kraft or Manila paper. When an insulating varnish is used instead of asphalt, the material is called Cable paper and is employed for wrapping cables. Cheesecloth is either bleached or unbleached, and is unfinished. For industrial uses it is not sized. It is in effect a loosely woven muslin, and shrinks on washing. Various grades are marketed. It comes in bolts, usually 36 in. in width. For polishing fresh enameled parts a fine grade known as Beef cloth, made of No. 22 yarn or finer, is preferred. Lighter grades of cheesecloth, with open weave, are known as Gauze and, in addition to the common surgical use, are employed as backing for paper and maps.

**Cherry.** The wood of several varieties of cherry trees native to Europe and the United States. The wood is brownish to light red in color, and darkens on exposure. The weight is about 40 lb. per cu. ft. The grain is close, firm, and even. It takes a beautiful polish, and is prized for cabinetwork, and for paneling and instrument cases. It is also used for small foundry patterns as a substitute for mahogany, as it retains its shape well. English cherry is from the trees *Prunus cerasus*, and *P. avium*. American cherry is from *P. aeritina*, the Black cherry, and from *P. emarginata*. Black cherry used for propellers has a specific gravity of 0.53 when oven dried. The compressive strength perpendicular to the grain is 1,170 lb. per sq. in., and the shearing strength parallel to the grain is 1,180 lb.

**Chestnut.** The wood of the tree *Castanea dentata*, growing along the Appalachian Mountains from New Hampshire to Georgia, and of several other species of *Castanea* native to Europe.

The trees grow to a large size and yield timbers suitable for large beams, but the wood is inferior to oak in strength, though similar in appearance. It is more brittle than oak, and the trees are often of spiral growth. The wood is hard, and has a coarse, open grain. The weight is about 38 lb. per cu. ft. The color is light brown to white. It is used for posts, crossties, furniture, veneers, and mill products. It is durable, but is now very scarce. Chestnut wood contains from 6 to 11 per cent of tannin, which is obtained by soaking the chipped wood in water and evaporating. Chestnut extract is valued for tanning leather, giving a light-colored strong leather.

**Chinese bronze.** A name used in the hardware industry to designate various grades of nickel bronzes and nickel brasses that have a white color. It requires at least 10 per cent of nickel to give brass or bronze a satisfactory white color that will not require plating in the finished article. When more than 15 per cent of nickel is used, the bronzes are difficult to machine; frequently a small amount of lead is added to make them free cutting. See Nickel brass.

**Chloride of lime.** Also known as Bleaching powder, and used widely for bleaching, as a disinfectant, and as a deodorizer. It is a white powder, a Calcium hypochlorate, of the composition $Ca(ClO)_2 \cdot 4H_2O$, having a strong chlorine odor. It decomposes easily in water. It is made by passing chlorine gas through slaked lime.

**Chlorinated hydrocarbons.** A great group of materials used as solvents for oils and grease, for metal degreasing, dry cleansing of textiles, refrigerants, insecticides, and for fire extinguishers. They were hydrocarbons (see Petroleum) in which hydrogen atoms have been replaced by chlorine atoms. They range from the gaseous methyl chloride to the solid Hexachlorethane, with most of them liquid. The increase in the number of chlorine atoms increases the specific gravity, boiling point, and some other properties. They may be divided into four groups: the methane group, including methyl chloride, chloroform, and carbon tetrachloride; the ethylene group, including dichlor-

ethylene; the ethane group, including ethyl chloride and dichlorethane; and the propane group. All of these are toxic, and the fumes are injurious when breathed or absorbed through the skin. Some decompose in light and heat to form more toxic substances such as phosgene. In their use as refrigerants, or in solvent baths, the metal equipment should be corrosion-resistant alloys to suit the particular hydrocarbon. Chloroform, known as Trichloromethane, is a liquid of the composition $CHCl_3$, boiling point 61.2°C., and specific gravity 1.489, used industrially as a solvent for greases and resins. It decomposes easily in the presence of light to form phosgene, and a small amount of ethyl alcohol is usually added to prevent decomposition. See also Carbon tetrachloride, Methyl chloride, Ethyl chloride.

**Chlorinated rubber.** An ivory-colored powder produced by the reaction of chlorine and rubber. It contains about 65 per cent by weight of rubber, and is represented by the empirical formula $C_{10}H_{13}Cl_7$. Rubber was first chlorinated in 1846 to improve its aging qualities, but was not marketed until about 75 years later. The first, produced by the United States Alkali Company, was known as Duroprene. Chlorinated rubber is used as a base in acid-resistant and corrosion-resistant paints, binders, adhesives, and plastics. The specific gravity is 1.5. It is readily soluble in hydrocarbons, ethylene dichloride, and carbon tetrachloride, but insoluble in water. For paints it is compounded and plasticized with gums and resins and produces a hard, tough film with good adhesion to metals. The uncompounded film is brittle. Tornesit is the trade name of chlorinated rubber materials produced by the Hercules Powder Company. Dartex and Alloprene are German chlorinated rubbers. Pliolite, of the Goodyear Tire & Rubber Company, produced with stannic chloride or chlorostannic acid, is not classed chemically as a chlorinated rubber. It contains about 95 per cent of rubber hydrocarbons. It is used in insulating compounds, adhesives, protective paints, and as a waterproofing medium. It is soluble in hydrocarbons, but will withstand acids and alkalies. Pliowax is this material mixed with paraffin or ceresin wax. Pliofilm of the same company is a rubber hydrochloride made by saturating the rubber molecule

with hydrochloric acid. It is made into transparent sheet wrapping material which heat-seals at 105 to 130°C., or it is used as a coating material for fabrics. It gives a tough, flexible, transparent, water-resistant film. See also Tensolite.

**Chlorine.** An elementary substance, symbol Cl, which at ordinary temperatures is a gas, $Cl_2$. Its name comes from its greenish-yellow color. It occurs in nature in great abundance in combinations, in such compounds as common salt. It has a powerful, suffocating odor, and is strongly corrosive to organic tissues and to metals. For bleaching it is widely employed in the form of compounds easily broken up. Dry chlorine may be used for detinning steel, and the recovered product, Tin tetrachloride, is used for weighting silk. Chlorine is made by the electrolysis of common salt. The specific gravity of the gas is 1.408, or 2.491 times heavier than air. The boiling point is −33.6°C., and it becomes liquid at atmospheric pressure at a temperature of −24.48°F. The liquid chlorine is shipped in steel cylinders of 10 to 150-lb. capacity. Its vapor pressure ranges from 39.4 lb. at the freezing point of water to 602.4 lb. at the boiling point of water. As a war gas it was known as Bertholite. The gas is not an intense poison, its action being one of irritation and not cumulative. The largest use of chlorine is for bleaching paper pulp and textiles, but it is also employed in the manufacture of carbon tetrachloride, phosgene, and other products.

**Chloropicrin.** A poisonous "gas" of the composition $CCl_3NO_2$, used with stannic chloride as a poison gas in chemical warfare, and in fumigating. It is a persistent lethal and lachrymatory poison. Chloropicrin is a colorless liquid made from picric acid. The specific gravity is 1.654, and boiling point 112°C. It is soluble in alcohol but insoluble in water. It was called Aquinite by the French, and Klop by the Germans. The chemical name is Nitrotrichloromethane, and it is also called Nitrochloroform. See also Poison gases.

**Chrome-molybdenum steel.** Any alloy steel containing chromium and molybdenum as the two predominating influencing alloying elements. Chromium gives unusual hardness and

toughness to the steel, while molybdenum increases the forging and machining properties. Chrome-molybdenum steels are noted for high strength and toughness. Only small amounts are used in the alloy. A chrome-molybdenum steel used in the form of tubing for airplane construction contains: chromium 0.80 to 1.10 per cent, molybdenum 0.15 to 0.25, manganese 0.40 to 0.60, and carbon 0.25 to 0.35. It has a tensile strength up to 95,000 lb. per sq. in., with elongation of 10 per cent, and is slightly air-hardening. It draws well, and tubes with a wall thickness of only 0.035 in. are made. Molybdenum also adds the quality of red hardness to steel to a greater degree than tungsten, and the amount used in these steels is sufficient to make them slightly red hard and air hardening.

S.A.E. steel 4140, with 0.80 to 1.1 per cent of chromium and 0.15 to 0.25 molybdenum, when oil quenched and drawn, has a tensile strength up to 260,000 lb. per sq. in., elongation 8 per cent, and Brinell hardness up to 490. The chrome-molybdenum steels marketed by the Crucible Steel Company under the name of Almo steel for airplane, automotive, and ordnance work have tensile strengths up to 167,000 lb. per sq. in., with elongation of 18 per cent. A chrome-molybdenum steel used for superheater tubes at 900 lb. per sq. in. pressure and 925°F., contains 5 per cent chromium and 0.50 molybdenum. Cromo steel, of the Michigan Steel Casting Company, is a chrome-molybdenum steel with a tensile strength of 100,000 lb. per sq. in. and elongation 15 to 25 per cent. It is used for large die blocks. Chrome-molybdenum steels, with more carbon, have great resistance to wear at high heat, and are valued for forging-die blocks. A tool steel marketed by Wm. Jessop & Sons, Inc., used for dies for stamping hard metals and called Albor die steel, contains 0.90 per cent chromium, 0.30 molybdenum, and 0.90 carbon. It is tough and deep hardening. Atlas No. 93, of the Ludlum Steel Company, is a shock-resisting tool steel with 0.65 per cent of chromium, 0.35 molybdenum, and 0.55 carbon. Chrome-molybdenum steel with carbon to 1.00 per cent is used for castings for bucket lips, crusher parts, and other heavy-duty parts. The cast steels have tensile strengths up to 150,000 lb. per sq. in., with elongation of 12 to 14 per cent.

**Chrome oxide green.** A pigment marketed in the form of dry powder, or ground in oil, and used in paints, enamels, and lacquers, or for coloring rubber. It is a bright-green, crystalline powder of the composition $Cr_2O_3$. The specific gravity is 5.20, and melting point 1990°C. It is insoluble in water. The dry pigment should have a minimum $Cr_2O_3$ content of 97 per cent, and not over 2 per cent should be retained on a No. 325 screen. The paste should contain 85 per cent of pigment and 15 per cent of linseed oil. Chrome oxide green is more permanent than chrome green, but is not so bright in color. Chrome green is a name given to a mixture of Prussian blue and chrome yellow. Guignet's green is the hydrated Chromium oxide. It is stable and odorless.

**Chrome-vanadium steel.** A chromium alloy steel containing a small amount of vanadium. The latter has the effect of intensifying the action of the chromium and the manganese in the steel. It also aids in the formation of carbides, hardening the alloy and increasing the ductility. The amount of vanadium is usually from 0.15 to 0.25 per cent. These steels are valuable where a combination of strength and elongation is desired. They resemble those with chromium alone, with the advantage of the homogenizing value of the vanadium. A chrome-vanadium steel having 0.92 per cent chromium, 0.20 vanadium, and 0.26 carbon has an elastic limit of 100,000 lb. per sq. in. and, when water-quenched from 1100°F., has an elastic limit of 150,000 lb. per sq. in., and an elongation of 16 per cent. Chrome-vanadium steels are used for such parts as crankshafts, propeller shafts, and locomotive frames. High-carbon chrome-vanadium tool steels are also marketed. They are mild-alloy tool steels of exceptional strength, toughness, and fatigue resistance. The chromium content is usually 0.80 per cent, with 0.20 vanadium. The grades vary with the carbon content, from 0.20 to 1 per cent. Arrow tool steels, of the Latrobe Electric Steel Company, contains 0.90 to 1 per cent chromium, 0.16 to 0.20 vanadium, 0.50 to 0.60 manganese, and 0.20 to 0.30 carbon. It is used for shafts, gears, and stressed parts. Crown steel, also of the same company, has higher manganese and up to 0.50 carbon. It is used for automobile springs, gears, crank pins, and tools. The tensile strength is

185,000 lb. per sq. in., and elongation 15 per cent. Milwaloy, of the Milwaukee Steel Foundry Company, is a casting steel. Grade 7 contains 1.5 to 1.75 per cent of chromium, 0.60 to 0.70 vanadium, and 0.30 to 0.40 carbon. H.Y.C.C. steel of the Crucible Steel Company, has high chromium and high carbon. It contains 0.25 per cent of vanadium, 12.0 chromium, and 2.25 carbon, and is used for wear-resistant dies.

**Chromic acid.** Also called Chromium trioxide. A red, crystalline, strongly acid substance of the composition $CrO_3$, used in chromium plating baths, for etching copper, in electric batteries, and in tanning leather. Chromic acid is produced by treating sodium or potassium dichromate with sulphuric acid. The specific gravity is 2.67 to 2.82, and the melting point is 196°C. It is easily soluble in water. Chromic acid is usually marketed in the form of porous red lumps. The dust is very irritating, and the fumes of the solutions are injurious to the nose and throat as the acid is a powerful oxidizing agent.

**Chromite.** An ore of the metal chromium, called Chrome ore when used as a refractory. It is found in small quantities in the United States, chiefly in Oregon and California. The composition of chromite is $FeO{\cdot}Cr_2O_3$, with the iron sometimes partly replaced by magnesium, and the chromium by aluminum. It is commonly massive granular, and the commercial ores contain only from 35 to 60 per cent of chromic oxide. The hardness is 5.5 and the specific gravity 4.6. The color is iron-black to brownish black, with a metallic luster. The melting point is about 3900°F., but when mixed in bricks with binders the fusion point is lowered. About half the world production of chromite comes from Rhodesia, and an extensive deposit is located near Ergani, Turkey. Other sources are India, Russia, New Caledonia, Cuba, and Greece. New Caledonia ore has 50 per cent chromic oxide, Turkish ore averages 48 to 53 per cent, and Cuban ore has only 32 per cent. The Indian chromite from Baluchistan is valued for refractory purposes. Chromite is employed for the production of chromium, ferrochromium, and in making chromite bricks and refractory linings for furnaces. Ores high in $Cr_2O_3$ and low in iron are preferred for metallurgical use. The hard lumpy ores

high in $Al_2O_3$ are used for refractories. For chemical use the ores must have more than 45 per cent chromic oxide, not more than 8 per cent silica, and be low in sulphur. For bricks the ground chromite is mixed with lime and clay and burned. A chrome-ore high-temperature cement marketed by the General Refractories Company under the name of Grefco has a fusion point of 3400°F. Chromite refractories are neutral and are resistant to slag attack. See also Firebrick.

**Chromium.** A metallic element, symbol Cr, employed very extensively in nickel alloys, alloy steels, and for chromium plating. As a plating metal it is very resistant to corrosion, and is also highly wear resistant. The color is silvery white with a blue tinge. When highly polished the metal is very smooth and water does not cling to it. Polished chromium-plated bearing surfaces can be run without oil. A chromium electroplate has a hardness of 9 on the Moh scale, or somewhat harder than case-hardened steel. It is inert to nitric acid, but dissolves in hydrochloric acid and slowly in sulphuric. When alloyed with steel in high percentages, it makes "stainless steel." Chromium occurs in nature only in combination with other elements. Its principal ore is chromite, and the metal is obtained by reduction and electrolysis. Chromium is a very hard metal with a specific gravity of 6.92 and an atomic weight of 52. Its melting point is 2750°F., and boiling point is 3992°F. The term Chromium metal usually indicates a pure grade of chromium containing 97 to 98 per cent of chromium and not more than 1 per cent of iron, with low carbon, 0.20 to 0.50 per cent. Chromium metal is used for making resistance alloys and special alloys; ferrochromium is used for the general addition of chromium to iron and steel. See Ferrochromium. Chromium plating is sometimes given trade names such as Aranium of Manning, Bowman & Company. For decorative purposes chromium plates as thin as 0.0002 in. may be used, but for wear-resistance plates up to 0.050 in. are used.

**Chromium copper.** An alloy of copper with chromium used in the foundry for introducing chromium into nonferrous metals, especially aluminum alloys, to give them high tensile strength. It is marketed in ingot or in "shot" form. A typical analysis of

Electromet chromium copper of the Electro Metallurgical Sales Corporation is: Chromium 8 to 11 per cent, copper 88 to 90 per cent, and a maximum of 1 per cent of iron and 0.50 silicon.

Copper-chromium alloys are high-strength copper alloys containing from 0.5 to 1.0 per cent of chromium. They are also known as Chrome copper, or Chromium copper. The drawn metals have high impact strength, and have an electrical conductivity of 80 per cent that of pure copper, or higher than that of copper hardened with silicon. A cast alloy containing 99.5 per cent of copper and 0.5 chromium, heat-treated, has a tensile strength of 45,000 lb. per sq. in., elongation of 25 per cent, and Brinell hardness of 100 to 120; the wrought metal has a tensile strength of 65,000 lb. per sq. in., elongation of 10 per cent, and Brinell hardness of 140. A chromium copper containing 0.50 per cent chromium is used for automotive cylinder heads, and is valued for this purpose because it has a thermal conductivity 80 to 85 per cent that of high-conductivity copper, or about twice that of aluminum alloy, or seven times that of cast iron. A wrought chrome copper of the American Brass Company contains 0.85 per cent chromium and 0.10 silicon. The tensile strength is 92,000 lb. per sq. in. and elongation 3 per cent. Chromium bronze, used for bearings, is a cast metal containing about 1 per cent chromium, 1 iron, and from 2 to 10 tin, with the balance copper. It has high strength and good wearing qualities.

**Chromium-nickel steel.** This name usually applies to a group of corrosion-resistant alloys, or austenitic steels, containing about 18 per cent of chromium and 8 per cent of nickel, as distinct from the high-strength nickel-chromium steels with small amounts of chromium. The patents are held by the Chemical Foundation. Chromium-nickel steels are marketed under trade names. Chromium-nickel steels are ductile and malleable. With low carbon they can be drawn and cupped, and are thus suitable for making utensils, although they harden rapidly with cold work and must be annealed after each draw or the steel tends to crack. About three times the power is required to draw an 18–8 steel as is required for an ordinary steel of the same carbon content. They are corrosion resistant and also resistant

to most acids. The tensile strengths range from 75,000 to 140,000 lb. per sq. in., with elongations of 30 to 65 per cent, and reduction of area of 25 to 75 per cent. The weights vary from 0.279 to 0.287 lb. per cu. in. When polished they have a brilliant white luster which does not dull on exposure.

Bethalon steel, of the Bethlehem Steel Company, is an 18–8 steel having a tensile strength of 90,000 lb. per sq. in., which, when fully heat-treated, has a tensile strength of 174,000 lb. per sq. in., and Brinell hardness of 352. Durco KA2S steel, of the Duriron Company, is an 18–8 casting steel with 0.07 per cent of carbon. Durco KA2SMo is a similar steel with 3 per cent of molybdenum. This latter steel has a tensile strength up to 95,000 lb. per sq. in., elongation 40 to 45 per cent, and Brinell hardness of 140. Allegheny metal, of the Allegheny Steel Company, is an 18–8 steel in several grades of carbon. Staybrite, of the Firth-Sterling Stainless Steels, Ltd., contains 0.20 carbon. Sta-Gloss, Hi-Gloss, and Duro Gloss are grades of stainless steel produced by the Jessop Steel Company.

Another group of corrosion-resistant irons and steels contain low nickel, about 1 per cent. They are termed Ferritic chromium-nickel steels, and have the general characteristics of the chromium stainless steels but are harder. Colonial 410, of this type, has 12.5 to 14.5 per cent chromium, 1 nickel, and 0.12 carbon. When heat-treated it has a tensile strength of 128,000 lb. per sq. in., elongation of 20 per cent, and Brinell hardness of 269.

Stainless U, of the Colonial Steel Company, is an 18–8 type with the addition of 1.5 molybdenum and 1.25 copper. It contains a maximum of 0.15 carbon. As rolled, it has a tensile strength of 100,000 lb. per sq. in. and elongation of 40 per cent. Circle L23-XM, of the Lebanon Steel Foundry, used for pump and valve parts in chemical plants, has 19.5 per cent chromium, 9 nickel, 3 molybdenum, and 0.15 carbon. The tensile strength is 82,000 lb. per sq. in. and elongation 30 per cent. Evansteel is a chromium-nickel cast steel in various grades produced by the Chicago Steel Foundry Company, containing either vanadium or molybdenum. It is used for gears, tractor shoes, dipper teeth, and chain links. Maxilvry steel, of Edgar Allen & Company, Ltd., is a chromium-nickel steel containing also copper. It is intended

chiefly for deep drawing. In the annealed condition it has a tensile strength of 40 tons per sq. in., elongation 68 per cent, and Brinell hardness of 149. See also Nickel-chromium alloys.

**Chromium-silicon steel.** A group of low-alloy steels used chiefly for springs containing from 0.90 to 1.10 per cent of chromium, 0.90 to 1.10 per cent of silicon, 0.60 to 0.70 manganese, and 0.40 to 0.45 carbon. They are hardened by quenching in oil, and have tensile strengths up to 225,000 lb. per sq. in. A Chrome-silicon steel of the Timken Steel & Tube Company, called Sicromo steel, contains more chromium and some molybdenum. The composition is 2.25 to 2.75 per cent chromium, 0.5 to 1.0 silicon, 0.4 to 0.6 molybdenum, and a maximum of 0.15 carbon. It has a tensile strength of 60,000 lb. per sq. in., elongation of 30 per cent, and hardness of 170 Brinell. It is a high-strength, shock-resistant steel. Chromium-silicon steels of higher chromium and silicon contents are in the class of heat-resistant alloys, and are used for valves for internal-combustion engines. Delhi A, produced by the Associated Alloy Steel Company, Inc., contains 17 to 19 per cent of chromium, 0.75 silicon, and 0.1 carbon. Delhi hard contains higher carbon, up to 1.1 per cent. Silcrome RA, of the Ludlum Steel Company, has 16 per cent chromium, 1 silicon, 1 copper, and 0.12 carbon. It is corrosion resistant, very ductile, and has a tensile strength up to 110,000 lb. per sq. in., and elongation of 25 per cent when heat-treated. Elcomet, of the La Bour Company, Inc., contains also nickel. It is used for valves and spinner heads. Still another class of chromium-silicon steel with about 10 per cent chromium and 3 to 4 per cent silicon is used for stainless cutlery. With about 0.45 carbon it will retain a fine cutting edge. Neva-stain steel, of the Ludlum Steel Company, is of this type. Silcrome No. 1, with 9 per cent of chromium and 3 per cent silicon, belongs to the type of steel most widely used for automobile engine valves.

**Chromium steel.** An alloy of steel with chromium. In the presence of carbon a chromium carbide is formed; and when other alloying elements are present, double or complex carbides are formed. Chromium refines the structure, increasing the tensile strength and elastic limit without loss of ductility. Chromium

steels have great resistance to wear and are valuable for tools, the usual chromium content for this purpose being about 2 per cent, although special steels with 12 to 17 per cent chromium and up to 2.5 per cent carbon have remarkable wear-resisting qualities, and are air-hardening or oil-hardening. Such steels are used for blanking and cold-forming dies for hard metals and for broaches and rolls. They are deep hardening and belong to the "non-deforming" class of tool steels. See Nondeforming steel. Chromium steels with about 1 per cent of chromium are used for gears and shafts. Uma steel No. 1, of the Republic Steel Corporation, has 0.55 to 0.75 per cent chromium, 0.35 to 0.65 manganese, and 0.15 carbon. It is a casehardening gear steel. Uma No. 5 has 0.85 to 1.10 per cent chromium, 0.70 to 0.90 manganese, and 0.50 carbon. It is deep hardening, with an ultimate strength up to 135,000 lb. per sq. in., and is used for transmission gears. Corten is the name of a low-alloy, high-tensile steel used for structural work. It contains 0.50 per cent chromium, 0.10 carbon, 0.10 manganese, 0.50 silicon, and 0.30 copper. The tensile strength is 65,000 lb. per sq. in., with elongation of 22 to 27 per cent.

Chromium steels with 3 to 4.5 per cent of chromium and 0.80 to 1 per cent of carbon are used for dies for hot pressing and forging. Chrome Die steel, of the Ludlum Steel Company, has 3.5 per cent of chromium and 0.90 carbon. A wear-resistant die steel marketed by the Carpenter Steel Company under the name of Hampden steel, contains 12.5 per cent chromium, 0.25 nickel, 0.25 manganese, and 2.10 carbon. It is deep hardening and has very high compressive strength, and is valued for forming rolls and spinning tools. A similar-purpose tool steel with air-hardening properties is Carpenter No. 610. It has 12 per cent chromium, 1.5 carbon, 0.80 molybdenum, 0.20 vanadium, and 0.30 manganese. Huron, of the Ludlum Steel Company, is a wear-resistant steel having 12.5 per cent chromium, 1 vanadium, and 2 carbon. It is used for dies. Nicroman is an "all purpose" tool steel of Henry Disston & Sons, Inc., with 1 per cent chromium, 1.65 nickel, 0.35 copper, and 0.70 carbon. Silcrome 46M, of the Ludlum Steel Company, has 4 to 6 per cent chromium, with 0.50 molybdenum, and 0.25 carbon. It has high strength at elevated temperatures. Uniloy chrome steels, of the Cyclops Steel Com-

pany, contain 4 to 6 per cent of chromium, 0.1 to 0.25 carbon, up to 0.60 manganese, with either molybdenum, 0.40 to 0.60 per cent, or tungsten 1 to 1.25 per cent. O-Hi-O, of the Vanadium-Alloys Steel Company, is an air-hardening die steel having 12 per cent chromium, 1.55 carbon, 0.85 vanadium, 0.40 cobalt, and 0.80 manganese. Croloy, of Henry Disston & Sons, Inc., is a similar high-carbon, high-chromium, die steel with vanadium and molybdenum. Hy-Glo Steel, marketed by the Latrobe Electric Steel Company, is a stainless steel used for cutlery and tools. It contains 17 per cent of chromium and 0.60 carbon. The Brinell hardness is from 196 to 600, with tensile strength from 110,000 to 250,000 lb. per sq. in. The hardened and polished steel is highly resistant to corrosion. See Stainless steels. Crocar, of the Vanadium-Alloys Steel Company, is a wear-resistant die steel of a composition similar to O-Hi-O, but with more carbon, 2.20 per cent.

Low-chromium steels with high carbon are used for balls and rollers for antifriction bearings. A steel with 1 per cent of carbon and 1.5 chromium has great crushing strength. Presto steel, of the Carpenter Steel Company, is a 1.40 per cent chromium steel of this class. Oildie steel, of the Columbia Tool Steel Company, is a nonshrinking, wear-resistant tool steel, having 1.6 per cent chromium, 0.45 tungsten, and 0.90 carbon, used for shearing and forming dies. Super die, of this company, contains 10.5 per cent chromium, 1 tungsten, and 1 silicon. See Chromium-tungsten steel. Chromium in steel also makes it corrosion and heat resisting. Silcrome 12 and Silcrome 17, of the Ludlum Steel Company, are steels of this type containing 12 and 17 per cent chromium, with 0.12 carbon. The latter will resist scaling up to 1550°F. Silcrome H-17 has 17 per cent of chromium and 1 carbon, and is a high-hardness heat-resisting steel. See Heat-resisting steel.

**Chromium-tungsten steel.** Any steel with chromium and tungsten as the predominating alloying elements, but usually steels with about 4 to 6 per cent of chromium and 0.78 to 1 per cent of tungsten employed for parts where resistance to hot chemicals is required, as in oil distillation. The small amount of tungsten gives a fine grain, increases the elastic limit, and makes

the steel more resistant to corrosion at elevated temperatures. It can be cast, forged, or rolled, and machines easily. Heat-treatment is required to develop the best properties. Steels with a high percentage of tungsten are called tungsten steel, even though the percentage of chromium may also be high. See Tungsten steel. A typical chromium-tungsten steel containing 6 per cent chromium, 0.70 tungsten, 0.50 manganese, and 0.25 carbon, cast and heat-treated, has a tensile strength of 125,000 lb. per sq. in., elongation 18 per cent, and Brinell hardness of 250. Allegheny 66, of the Allegheny Steel Company, contains 15 to 18 per cent chromium, 2.5 to 3.5 tungsten, and a maximum of 0.12 per cent carbon. Hot-rolled it has a tensile strength up to 160,000 lb. per sq. in., with elongation of 10 per cent and Brinell hardness of 312. Cro-Tung is a chromium-tungsten steel marketed by Industrial Steels, Inc.

**Chrysotile.** A fibrous variety of the mineral Serpentine, which is the chief source of the American asbestos. It is a hydrated silicate of magnesia of the composition $2SiO_2 \cdot 3MgO \cdot 2H_2O$. It is a widely distributed mineral, and comes from Quebec, Vermont, New York, New Jersey, and Arizona. See Asbestos.

**Cinnabar.** The chief ore of the metal mercury. As a pigment it was originally called Minium, a name now applied to red lead. It is a Mercuric sulphide, HgS, which when pure contains 86.2 per cent of mercury. The ores, however, are usually poor, containing clay, iron oxide, and other materials. The best ores run up to about 7 per cent of mercury, but the average American ore has only 0.5 per cent. Italy, Spain, United States, and Mexico are the leading producers. Cinnabar has a massive granular structure with a hardness of 2 to 2.5, a specific gravity of about 8, and usually a dull earthy luster. It is brownish red in color. Chinese cinnabar is ground as a fine scarlet pigment for inks. Cinnabar is not smelted, the extraction process being one of distillation, made possible by the low boiling point of the metal. Cinnabar is also called Liver ore. Another ore of mercury found in Mexico is Livingstonite, $2Sb_2S_3 \cdot HgS$. It is a massive, red-streaked mineral of specific gravity 4.81 and hardness 2. Calomel, a minor ore in Spain, is a white to gray crystalline mineral of

the composition $Hg_2Cl_2$ with specific gravity of 6.5. The ore found in Colorado and known as Coloradoite is a Mercuric telluride, HgTe. It has an iron-black color and a specific gravity of 8. Tiemanite, found in California and Utah, is a Mercuric selenide, HgSe, having a lead-gray color and a specific gravity of 8.2. There are more than 20 minerals which may be classed as Mercury ores.

**Clay.** The general name for all earths that form a paste with water and harden when heated. The U.S. Department of Agriculture distinguishes clay as having small grains, less than 0.002 mm. in diameter, while Silt has grains from 0.002 to 0.05 mm. Most clays are composed chiefly of silica and alumina, and the clayey mineral in all clays is kaolinite or minerals closely allied, as Anauxite, $Al_2O_3{\cdot}3SiO_2{\cdot}2H_2O$, and Montmorillonite, $Al_2O_3{\cdot}4SiO_2{\cdot}2H_2O$, the latter serving to increase the bond strength of ceramic clays. Some clays, however, derive much of their plasticity from colloids of organic material. Clays are used for the manufacture of bricks, tiles, pipes, pottery, and porcelain. When subjected to high heat, clays become hard, brittle, and insoluble in water. Clays that are not easily worked are made more plastic by alkaline starch solutions, ammonium alginate, or other materials. A plasticizer known as Plasticede contains tannin and lignin. Artificial plasticizers sometimes add to the strength. Kaolins are the purest forms of clay. Clays with 1 per cent of iron burn red, and titanium increases this color. Yellow ochres contain iron as a free hydrate. All clays contain quartz sand and sometimes mica. Fireclay is a refractory clay containing only a small amount of alkali, and is capable of withstanding high temperatures. Calcareous clays are known as marls. Pyrites burn to holes in the brick bordered by a black ring of magnetic oxide and are objectionable. Limestone in grains burns to free lime which later slakes and splits the bricks. Most of the common brick clays are complex mixed earths. See also Kaolin, Firebrick, Fireclay, Bentonite.

**Clock brass.** A copper alloy containing approximately 63 per cent of copper, 35 per cent of zinc, and 2 per cent of lead. It is a leaded high brass. The lead gives it the quality of free cutting,

and it can be blanked and turned with clean sharp edges. It gets its name from the fact that it is especially suitable for small clock gears and clock frames stamped from sheets. It is not suited to forming or cupping operations, as it is too brittle to draw easily. The tensile strength, hard rolled, is about 65,000 lb. per sq. in. and elongation 20 per cent. Hooker brass is an old name for this alloy. In hard-rolled sheets this brass is also called Engravers' brass. See Brass, and Leaded high brass.

**Coal.** A general name for a black mineral formed of ancient vegetable matter, and employed as a fuel and for destructive distillation to obtain combustible gases and carbohydrate products. See Coke, Benzene, Ammonia, Tar. Coal is composed largely of carbon with smaller amounts of hydrogen, nitrogen, oxygen, and sulphur. It was formed in various geological ages and under varying conditions, and occurs in several distinct forms. Peat is the first stage, followed by lignite, bituminous, and anthracite, with various intermediate grades. See Anthracite, Lignite, Bituminous coal, and Cannel coal. The mineral is widely distributed in many parts of the world. The value of coal for combustion purposes is judged by its fixed carbon content, volatile matter, and lack of ash. It is also graded by the size and percentage of lumps. Finely ground, or Powdered coal, is used for burning in an air blast like oil. The percentage of volatile matter declines from peat to anthracite, and the fixed carbon increases. A good grade of coal for industrial power-plant use should contain 55 to 60 per cent of fixed carbon and 30 to 37 per cent of volatile matter, and not exceed 8 per cent of ash. The B.t.u. value should be 13,500 to 14,000 per lb. Coal in its natural state absorbs large quantities of water, and also because of impurities and irregular sizes, is not as efficient as the Reconstructed coal and Patent fuels which are made by crushing and briquetting lignite or coal and waterproofing with a coating of pitch. Reconstructed coals are widely used in Europe.

**Cobalt.** An elementary metal, symbol Co, obtained chiefly from cobaltite and smaltite. The metal is obtained from the ores by smelting in a blast furnace and then treating the arsenides in acids from which the cobalt hydroxide is precipitated. This is

changed to the oxide by heating. Cobaltite, or Cobalt glance, found in Ontario, is a sulph-arsenide of the metal, CoAsS, and occurs with Gersdorffite, NiAsS. It is tin white with a reddish hue, of specific gravity 6. Cobalt is also produced from the copper ores of the Belgian Congo and northern Rhodesia, and these ores form the chief source of commercial cobalt. The Burma ore is a lead-zinc ore from which the speiss is a nickel-cobalt mineral with 7 per cent of cobalt.

Cobalt is a white metal resembling nickel but with a blue tinge. Its power of whitening copper is inferior to that of nickel, but its blue neutralizes the yellow of nickel in nickel alloys. It is hard, tough, malleable, and refractory. The specific gravity is 8.756, and melting point 2672°F. The tensile strength of pure cast cobalt is 34,500 lb. per sq. in.; with 0.25 per cent of carbon this is increased to about 62,000 lb. per sq. in. Its chief use is for alloying with steel, giving great hardness and adding red hardness. See Super high-speed steel. The metal is allied to nickel, but is not ordinarily used in nonferrous alloys like nickel. It is used also in magnet steels, and in red-hard cutting alloys. It is marketed extensively in the form of its oxides for various uses. Crobalt is a trade name for a cutting alloy of the Michigan Tool Company used for tools and wear-resistant parts. See Cutting alloys and Nickel-cobalt alloys. Cobalt has become of increasing importance as an alloying element also with copper. An alloy developed by the Westinghouse Electric & Manufacturing Company under the name of Cuferco has the same tensile strength as carbon steel, and has high mechanical endurance, with an electrical conductivity 70 per cent that of copper.

**Cobalt oxide.** A steel-gray to blue-black powder employed chiefly as a base pigment for ceramic grazes on metal, and as a colorant for glass. It gives excellent adhesion to metals and is valued as an undercoat. It is also one of the most powerful colorants for glass, 1 part in 20,000 parts of a batch giving a distinct blue color. Cobalt oxide is produced from treatment of cobalt-nickel ores, and has the composition $Co_3O_4$, but the oxide commercially known as Black cobalt oxide may be a mixture with $Co_2O_3$, and is Cobaltous-cobaltic oxide. The two classes are

called RKO and SKO grades, with specific gravities ranging from 5.8 to 6.3. Gray cobalt oxide has the composition CoO, but this form and $Co_2O_3$ are unstable and change to $Co_3O_4$ on heating. Cobalt oxide is also used as a catalyst in the chemical industry.

**Cobalt steels.** Cobalt in small amounts is alloyed with special steels to give hardness and tenacity. With chromium it develops these properties in the steel to a greater extent. It is also used in high-speed steels to give added red hardness and toughness. Rex 95, of the Crucible Steel Company, is typical of this use. It contains 5 per cent of cobalt, 14 tungsten, 4 chromium, 2 vanadium, and 0.50 molybdenum. Imperial Major, of A. Milne & Company, has 12 to 13 per cent cobalt with 22 tungsten. It has high wear resistance when cutting at red heats. See Super high-speed steel. Cobalt steels are also used for magnets. See Magnet steels.

**Cochineal.** A dyestuff of animal origin, which before the advent of aniline dyes was one of the most important coloring materials. Cochineal is the female of the *Coccus cacti*, an insect which feeds on various species of cactus in Mexico. The insects have no wings, and at the egg-laying season are brushed off the plants, killed by boiling, and dried. They are dark reddish brown in color. Cochineal contains from 10 to 20 per cent of pure coloring matter, carminic acid, mostly in the eggs, from which the Carmine red, $C_{11}H_{12}O_7$, is obtained by boiling with mineral acid. Carmine red produces brilliant lake colors of various hues with different metals. Commercial cochineal is often adulterated with starch, kaolin, red lead, or chrome-red. The brilliant red pigment known as Carmine lake is made by precipitating a mixture of cochineal and alum.

**Cocobola.** The wood of a hardwood tree of Central America of undesignated species. It is a beautiful wood, extremely hard, and very heavy, the weight being 75 to 85 lb. per cu. ft. It has orange and red bands with dark streaks, and takes a fine polish. The commercial wood comes from Panama and Costa Rica, and is used for canes, turnery, inlaying, and handles. Cocos-wood, also called Cocoa wood and West Indian ebony, used chiefly for

inlaying, is from the tree *Brya ebenus*, of tropical America. The sapwood is light yellow and the heartwood is brown, streaked with yellow. The grain is fine, dense, and even, and the wood hard and heavy.

**Coir.** A fiber by-product of the coconut industry. The fiber is soaked and beaten from the husks and then combed and bleached. The coarse and long fibers are used for brush making, the finer and curly fibers being spun into coir yarn which is used for mats, cordage, and coarse cloths. It can be dyed. The Ceylon coir yarn is sold in two quality grades, Kogalla and Colombo, with subdivisions according to thickness and texture.

**Coke.** The porous, gray, infusible residue left after the volatile matter is driven off of bituminous coal. The coal is heated to a temperature of 1200 to 1400°C., without allowing air to burn it, and the volatile matter expelled. The residue, which is mainly fixed carbon and ash, is a porous, cellular material of great strength. Its structure and nature make it a valuable fuel for blast furnaces, burning rapidly and supporting a heavy charge of metal without packing. Soft, or bituminous, coals are designated as coking or noncoking according to their capacity for being converted into coke. Coke is produced in the beehive and by-product ovens, or is a by-product of gas plants. One ton of coal will yield an average of 0.7 ton of coke, 11,500 cu. ft. of gas, 12 gal. of tar, 27 lb. of ammonium sulphate, 50 gal. of benzol, 0.9 gal. of toluol and naphtha, and 0.5 lb. of naphthalene. The fixed carbon of coke should be at least 86 per cent, ash less than 12 per cent, and sulphur not over 1 per cent. The porosity may vary from 40 to 60 per cent, and the apparent specific gravity should not be less than 0.8. A foundry coke should have an ignition point of about 1000°F., with sulphur below 0.7 per cent, and the pieces should be strong enough to carry the burden of ore and limestone. Semicoke and Smokeless fuel are coals carbonized at low temperatures and briquetted for household use. Coalite is an English name for fuel of this type, and Carbolux is a French household coke. Foundry coke is screened coke above 2½ in. in diameter. Domestic coke is smaller.

**Cold-molded plastics.** Materials used for molding mechanical and electrical parts under simple pressure. No chemical transformation takes place as with synthetic molding resins. They are usually mineral resins or bituminous materials such as gilsonite, with drying oils, driers, and fillers. The fillers are usually mineral, silica, talc, kaolin, or asbestos fiber, to add strength and heat resistance, and they may be as high as 80 per cent of the total. The plastics will usually withstand temperatures up to about 600°F., although the melting point of the original bituminous binder is from 180 to 212°F. They are black in color, insoluble in water, good electrical insulators, heat resistant, but have only about half the strength of synthetic molding plastics. See Gummon. Aico, of the American Insulator Company, is a cold-molded plastic of this type. Some other cold-molded plastics are: Ebrok, of the Richardson Company; Okon, of the American Hard Rubber Company; and Thermoplax, of Cutler-Hammer, Inc.

**Cold-rolled steel.** Low-carbon, open-hearth steel that has been worked into strips, sheets, or bars by cold-rolling. The carbon content is usually from 0.08 to 0.12 per cent, but higher carbon may be used, and the standard cold-rolled shafting runs from 0.26 to 0.32 per cent. The manganese is usually from 0.30 to 0.80 per cent. After the regular hot-rolling has been completed on sheets, they are annealed and pickled, and then passed cold through finishing rolls, which smooth and polish the surfaces, and increase the hardness and tensile strength of the sheet. Only a slight reduction is made in the sheet by cold-rolling. For the making of cold-rolled strip steel the slabs after hot-rolling are sheared to the desired length, then hot rolled into strip which is wound on a coil. The coils are re-coiled to loosen the scale, pickled, rolled in breakdown mills, and annealed. The cold-rolling is then accomplished until the desired hardness is obtained. It is usually in four tempers, but sometimes in six, from No. 1, hard, to No. 6, dead soft. Dead soft steel is for severe drawing and cupping work. It has a minimum tensile strength of 37,500 lb. per sq. in. and an elongation of 40 per cent. Medium soft, or quarter soft, is for forming or

light drawing. The minimum tensile strength is 42,500 lb. per sq. in. and the elongation 20 per cent. Medium hard, or half hard, is for bending at sharp right angles across the grain. The tensile strength is 50,000 lb. per sq. in. Hard rolled is for flat work and easy punching. The minimum tensile strength is 55,000 lb. per sq. in., and the elongation is 5 per cent. Specifications for cold-rolled sheet steel for automobile bodies call for less than 0.14 per cent carbon, under 0.60 manganese, and under 0.045 each of sulphur and phosphorus. The average tensile strength of the normalized sheet is 50,000 lb. per sq. in.

Cold-drawn steel is bar or rod steel which has been finished by drawing through dies. Cold drawing doubles the yield point of hot-rolled bars. The tensile strength of commercial low-carbon cold-drawn steel is 70,000 lb. per sq. in., yield point 60,000 lb. per sq. in., and elongation 15 per cent. Cold drawing imparts a high finish. Rycase is the name of a low-carbon, high-manganese, cold-drawn steel of Joseph T. Ryerson & Son, Inc., used for spindles to be casehardened. The tensile strength is 75,000 lb. per sq. in.

**Columbite.** An ore of the metal columbium. Its composition varies and may be $FeO \cdot Cb_2O_5$ or $(FeMn)Cb_2O_6$, or it may also contain tungsten and other metals. It is produced chiefly in Nigeria and marketed on the basis of the $Cb_2O_5$ content. The combined mineral known as Colombo-tantalite, mined in South Dakota and in the Belgian Congo, is marketed on the basis of total $Ta_2O_5 \cdot Cb_2O_5$ content. As the tantalum increases and replaces the columbium, the specific gravity increases.

**Columbium.** An elementary metal, symbol Cb. It is called Niobium in Germany, with the symbol Nb. It occurs in the minerals columbite and tantalite, and as it closely resembles tantalum is difficult to separate from it. Columbium has a specific gravity of 8.33, a melting point of 1950°C., and is ductile and malleable. It is insoluble in most acids and not easily attacked by alkalies. Like tantalum, it has the property of absorbing gases at high temperature, which makes it useful as plate and grid metals in high-vacuum tubes. The metal has a more beautiful white color than tantalum, and is used for watch cases

and jewelry. It is used in stainless steels in small quantities for inhibiting intergranular corrosion. Allegheny 46 is a steel of this class. Ferrocolumbium, for adding columbium to steel, is marketed as an alloy containing 50 to 60 per cent of columbium and 7 per cent of silicon. Columbium carbide, used for cutting tools in the same way as tantalum carbide, is an extremely hard crystalline material of the composition CbC, with a melting point of about 3800°C. It is made by sintering powdered columbium and carbon in a hydrogen furnace.

**Commercial bronze.** A brass which derives its name from its bronze color. It contains 90 per cent of copper and 10 zinc, and is a standard product of the brass mills. The weight is 0.318 lb. per cu. in., and the tensile strength is from 35,000 to 100,000 lb. per sq. in. depending upon the hardness. It is very ductile, but may sometimes contain 0.5 per cent of tin, which increases the hardness and strength but lowers the ductility. Hardware bronze is this alloy modified with about 2 per cent of lead, and is a casting metal. The Hardware bronze of the Chase Brass & Copper Company contains 86 per cent of copper, 12.85 zinc, and 1.75 lead. Commercial bronze, of the Buckeye Brass & Manufacturing Company, contains 83 per cent of copper, 7 tin, 7 zinc, and 3 lead and is a composition brass. See Brass.

**Composite metals.** Sheet or plate metal having a face of special resistant metal with a backplate of lower-cost metal. The term usually refers to steels, since the other composite metals are known as Duplex metal or by special terms. See Alclad, Doublé, and Bi-metal. Composite steel originally meant only tool-steel sections inserted in nonhardenable low-carbon steel, used for die parts and shear blades, but the term now has a wider significance. Composite steel sheets are made by rolling together the two metals, obtaining a bond by adhesion, or by resistance welding to obtain cohesion. Croloy, of the Babcock & Wilcox Company, is a bonded plate consisting of a thin sheet of stainless steel welded to a base plate of carbon-molybdenum steel, with a sheet of nickel welded between the two to prevent migration of the carbon. Ingaclad, of the Ingersoll Steel and Disc Company, consists of stainless steel bonded to carbon

steel plate. Silver-Ply is a stainless-clad steel of the Jessop Steel Company.

**Composition brass.** A general name for a casting alloy which has a mid position between the brasses and the bronzes. Under the name of Ounce metal, and also under the designation "85-5-5-5," it has been one of the most widely used "brasses" for bearings and for a wide variety of machine parts. It will withstand hydraulic pressure, and is used for valves and fittings. It casts and machines readily, has a tensile strength from 26,000 to 32,000 lb. per sq. in., and an elongation of 20 to 25 per cent. It takes a fine polish. This alloy is used for the so-called bronze pipe fittings, and has the same coefficient of expansion as copper. See also Yellow ingot metal. Some makers vary the composition. Johnson bronze No. 44, for bearings, contains 88 per cent copper, 4 tin, 4 lead, and 4 zinc. The A.S.T.M. specifications for composition brass call for 84 to 86 per cent of copper, 4 to 6 of zinc, 4 to 6 of tin, and 4 to 6 of lead. It may contain up to 0.75 per cent of nickel and small amounts of iron, either as intentional additions to increase strength or as impurities. The minimum tensile strength is 26,000 lb. per sq. in., yield point 12,000 lb. per sq. in., and elongation 15 per cent. Aluminum, even in small amounts, decreases the strength and ductility, and is not considered desirable in this type of alloy. See Hydraulic bronze.

**Concrete.** One of the most widely used construction materials. It is composed of portland cement, sand, and gravel or broken stone, in the proportions 1 volume of cement to 2 of sand and 4 of stone, but these proportions are varied according to the strength and other qualifications required. It is practically artificial rock. The quality of concrete is usually judged by its compressive strength. A "rich mixture" for columns and highly stressed structures is 1:1:3. A "lean mixture," used for unimportant foundations, is in the proportion of 1:3:6. After 28 days setting, rich-mixture concrete should have a compressive strength of 2,800 lb. per sq. in., standard mixture 2,200 lb. per sq. in., and lean mixture 1,400 lb. per sq. in. The sand used in concrete is usually roughly angular, and the stone sharply

broken. The weight of concrete varies according to the type and quality of rock and sand employed. A limestone concrete will weigh about 150 lb. per cu. ft.; the same mixture in trap rock may weigh 155 lb. per cu. ft. Reinforced concrete is a combination of concrete with a steel internal structure generally composed of rods. It has more strength. Reinforced concrete is extensively used in buildings, bridges, telegraph poles, roads, and fences. See also Cement mortar. Nonslip concrete, for steps, is made by applying aluminum oxide grains, sizes 3 to 60 mesh, to the concrete before it hardens. Insulating concrete and light-weight concretes are made by special methods, or by the addition of spongy aggregates. Slag may be used for this purpose. Aerocrete is a patented porous light-weight concrete produced by adding aluminum bronze powder to the cement. The reaction between the flakes of metal and the lime in the cement forms hydrogen and causes bubbles. This concrete is a heat and sound insulator but is not strong. Haydite is a patented light-weight aggregate made by burning shale in a rotary kiln, which produces a material of expanded cellular structure. The final product is composed of about 60 per cent silica, 16 alumina, with lime and other materials. Haydite concrete weighs below 100 lb. per cu. ft., but is not as strong as gravel concrete. Superock and Waylite are trade names for expanded aggregate made by treating molten slag with water or steam. Calicel, of the Keasbey & Mattison Company, is a light-weight spongy aggregate made by fusing silicates of lime and alumina and cooling to produce a stone of cellular structure. Light-weight insulating concrete under the name of Microporite is made in Germany from ground silica and lime hardened by steam treatment.

**Constantan.** A cupro-nickel alloy containing 45 per cent of nickel and 55 per cent of copper. It is used chiefly for pyrometer and electrical resistance wires. When cold drawn it has a tensile strength up to 140,000 lb. per sq. in. It is resistant to oxidation and corrosion, has an electrical resistivity of 294 ohms per circular mil ft., with a constant temperature coefficient of resistance; for low-temperature pyrometers it has a high thermo-

electric effect against copper or iron. The melting point is 1290°C. Cupron of the Wilbur B. Driver Company, and Advance metal, of the Driver-Harris Company, are trade names for the alloy.

**Coolants.** Liquids employed for quenching steels in heat-treating, although this term is also used to designate liquids employed on machines to cool the work and improve the cutting. See Soluble oils. Quenching baths for steel are now most usually of oil. See Quenching oils. But when water is used for the normal water-hardening steels, it may be modified with soda or other material to give more uniform cooling. A water bath containing 5 per cent of sodium hydroxide is claimed to give uniform rapid cooling. Common salt is also used in coolant brine baths, but has the disadvantage of corroding the metal. A weak solution of sulphuric acid was formerly used as a coolant.

**Copal.** A general name for fossil and other resins found in nearly all tropical countries, and used in making varnishes and lacquers, and in adhesives. The hardest and most prized varieties come from Africa. Zanzibar copal, from the tree *Trachylobium verrucosum*, is the hardest varnish resin, with a melting point of 240 to 360°C., compared with 180 to 200°C. for Congo copal. The latter is largely fossil. Lisbon copal is a variety of Congo copal from Guinea. Madagascar copal is from the tree *Hymenaca verrucosa*, and is darker than Zanzibar. Many varieties of *Hymenaca* of tropical America furnish copals marketed as Demerara gum, Locust gum, and other names. All of the copals are soluble in alcohol, linseed oil, and turpentine. Congo resin is the most insoluble of the natural resins, but after thermal processing it is soluble in a wide range of solvents in a manner similar to drying oils. The specific gravity of copals is from 1.04 to 1.13. The colors vary from white through yellow, red, brown, to brownish black. The commercial copals are classed in five groups: East African, West African, Manila, East Indian, and South American. The name copal is applied in the East Indies to the resin of the tree *Agatha alba*, closely related to the Kauri pine. See White dammar. There are seven grades of copal, from the No. 1 pale, scraped chunks, to the No. 7 dust. Hard copal is harder than dammar, and has

a higher melting point, but the hardness of the resins depends greatly upon the seasoning time in the ground. The semihard and soft copals are produced directly from the trees by tapping. The melting point of a copal from *A. alba*, collected one day after tapping averages 85°C., compared with 105°C. when collected three months after tapping. Copals are distinguished by their solubility in chloral hydrate. See also Animi gum.

**Copper.** One of the most useful of the metals, and probably the one first used by man. It is found native and in a large number of ores. The chemical symbol is Cu. It is yellowish red, tough, ductile, and malleable, gives a brilliant luster when polished, has a disagreeable taste and a peculiar odor. It melts at 1981°F. The specific gravity is 8.91, and weight 0.321 lb. per cu. in. It is the best conductor of electricity next to silver, with a conductivity 92 per cent that of silver. The coefficient of expansion is 0.000017 per deg. C. The tensile strength of cast copper is from 17,000 to 20,000 lb. per sq. in. with elongation of 40 to 50 per cent. Annealed wrought copper has a strength of 32,000 lb. per sq. in., with elongation of 56 per cent, while cold-drawn metal has a tensile strength of 56,000 lb. per sq. in. with elongation of 6 per cent. The Bus-bar copper used by the electrical companies has a tensile strength up to 40,000 lb. per sq. in. Pure copper is difficult to cast because the molten metal absorbs oxygen, forming oxides and gases.

Copper is used for electrical conductors, for making brasses and bronzes, for sheathing, fittings, and for cast articles. Small amounts of copper are added to some steels to give corrosion resistance. The United States produces more than half of all copper. Chilean and Belgian Congo copper are next in importance. Secondary copper is a term used to designate copper recovered from smelting scrap and old copper alloys. The production of secondary copper is about 40 per cent the production of new copper.

Copper does not have the ductility of brass for metalworking, but does not work-harden as rapidly as brass. Much of the copper marketed for commercial use as copper contains slight amounts of silicon or other hardener to give the wear-resistance and

strength needed, although these materials decrease the electrical conductivity. About 25 per cent of the copper used in the United States goes into electrical manufactures and about 15 per cent into electrical wiring. It is produced largely in the Rocky Mountain States.

The average copper content of the copper ores mined in the United States is 1.6 per cent, which is concentrated to 15 or 20 per cent. After smelting, much of it is refined electrolytically. Electrolytic copper has a purity not less than 99.9 per cent. Copper is marketed in three general grades: Electrolytic, Lake, and Casting. More than half is sold in Wirebars of about 200 lb. for rolling and drawing. Commercial wrought copper in bars, wire, sheets, and rods, is marketed as Electrolytic tough pitch, Oxygen free copper, Phosphorized copper, and Arsenical copper. Electrolytic tough pitch, or High-conductivity copper, oxidized with phosphorus without residue and annealed, has an electrical resistance of 0.67879 microhm per in. cube at 20°C., which is taken as 100 per cent conductivity. This copper has the disadvantage of becoming brittle when heated and of not giving a high finish. But even as little as 0.40 per cent of arsenic or other impurity will reduce the conductivity drastically. Oxygen-free copper has high conductivity, is not subject to brittleness, and will withstand more cold-working. Phosphorized copper contains residual phosphorus. It has high strength but lower conductivity. Arsenical copper has low conductivity but is resistant to corrosion. Anaconda condenser tubes of arsenical copper contain 0.25 per cent of arsenic. Lake copper, from the Lake Superior region, usually contains arsenic. Hard-drawn wire or sheet arsenical copper has a tensile strength of 60,000 lb. per sq. in.; the annealed material has a strength of 32,000 lb. per sq. in. and elongation of 45 per cent. Cast copper has only 80 to 90 per cent the conductivity of wrought copper. Electro-sheet copper is thin sheet copper produced by electrodeposition. It is marketed by the American Brass Company in roll sheets of 1 oz. to 7 oz. per sq. ft. (0.0013 to 0.0094 in.), used for roofing and damp proofing. A special grade of copper having high ductility, high conductivity, and fatigue resistance is made without melting by con-

verting electrolytic cathode copper directly into rods and strips by rolling at elevated temperature in a reducing atmosphere. The Phelps Dodge Copper Products Corporation produces this copper under the name of PDCP copper.

Braziers' copper is a term used to designate heavy sheets of copper weighing from 1.5 to 6 lb. per sq. ft., used for coppersmiths' work. Roofing copper is usually 10-oz. sheet. Coppersmiths' copper is hot-rolled, soft-temper, heavy sheets up to ½ in. Copper foil is sheet copper less than 0.005 in. in thickness. Copper powder is chemically reduced copper in noncrystalline form. It is used in a liquid vehicle for copper coating, or for sintering. Copper powder of the Nichols Copper Company is 98.3 per cent pure, and all particles pass through a 350-mesh screen. Copper shot is copper in the form of round globules, used chiefly in jewelry manufacture in alloying gold and silver. Leaded copper is copper in commercial rods and shapes containing a small amount of lead to make it free machining.

**Copper acetate.** Also known as Crystals of Venus. A dark green crystalline poisonous powder of the composition $(CH_3COO)_2Cu \cdot H_2O$, used in the manufacture of paints, lacquers, linoleum, inks, and for making artificial verdigris on copper articles. It is soluble in water and alcohol.

**Copper aluminum.** A master alloy used for making aluminum alloys. It usually contains 50 per cent copper and 50 aluminum, and melts at 1070°F.

**Copper carbonate.** Also called Artificial malachite. A green, poisonous powder of the composition $Cu_2(OH)_2CO_3$, used as a paint pigment. It is made by adding sodium carbonate to a solution of copper sulphate. The specific gravity is 3.7. It is insoluble in water.

**Copper-lead alloys.** A group of alloys used in bearings. Copper absorbs only about 3.5 per cent of lead, and the alloys are difficult to cast without separation of the lead unless melted with a catalyzer such as nickel. Copper-lead bearing metals are made by sintering together copper powder and copperplated lead powder. A British copperlead for automobile main bearings

contains 55 to 75 per cent of copper and the balance lead. It has a tensile strength of 8 tons per sq. in. with elongation of 15 per cent. Lead bronze, of the British Air Ministry, contains 75 per cent of copper and 25 lead, modified with 1 to 2 per cent of tin. Most of the commercial copper-lead alloys also contain some tin. See High-lead bronze.

**Copper ores.** There are 15 copper ores of industrial importance. The most important ore of copper is Chalcopyrite, also known as Copper pyrites, and Yellow copper ore. It occurs widely distributed, associated with other minerals, and may carry gold or silver. It is the chief ore of the copper mines in England, Sweden, Spain, Canada, South Africa, Chile, and many parts of the United States. Chalcopyrite is a sulphide of copper and iron, $CuFeS_2$, containing theoretically 34.5 per cent of copper, and 30.5 per cent of iron. It usually occurs massive, with a hardness of 3.5 and a specific gravity of about 4.2. The color is brass-yellow, with greenish-black streaks. To obtain the copper the ore is first smelted to matte instead of to the metal. This matte is a mixture of $Cu_2S$ and FeS, together with impurities. Enough sulphur is supplied in melting to combine with all of the copper. The matte is then poured into a reverberatory furnace where air is blown through, converting the iron to iron oxide, and the sulphur to sulphur dioxide. No fuel is used. When the sulphur is gone, the copper is cast into pigs, which are called Blister copper, due to the blistered appearance. Blister copper contains from 96 to 99 per cent of copper, with various metals and arsenic and sulphur as impurities. It is not used commercially, but is refined in furnaces or electrolytically.

Chalcocite is another important ore. It occurs in Montana and Arizona, and with other minerals in Alaska, Chile, Peru, Mexico, and Bolivia. It is a Cuprous sulphide, $Cu_2S$, containing theoretically 79.8 per cent of copper. It usually occurs massive, but crystals are also found. Its hardness is 2.5 to 3, and the specific gravity is 5.5. It has a shining lead-gray color. Tennantite, or Gray copper ore, found in Colorado, Wyoming, and Montana, has the composition $3Cu_2S{\cdot}As_2S_3$, with sometimes

antimony. When much of the arsenic is replaced by antimony it is called Tetrahedrite.

Azurite is an important ore found with other copper ores. It is a basic carbonate of copper, $Cu(CuOH)_2(CO_3)_2$, occurring in azure-blue crystals. It is also called Blue copper carbonate and Chessylite.

Cuprite, also called Red copper ore, is a Cuprous oxide, $Cu_2O$, containing theoretically 88.8 per cent of copper, and occurs usually massive, but sometimes in crystals. The specific gravity is 6 and the hardness is 3.5 to 4. The color may be various shades of red, with an adamantine luster in the clear crystallized form, or a dull earthy luster in the massive varieties. Cuprite is found in the copper deposits in Arizona, and is one of the ores in Chile, Peru, and Bolivia.

Chrysocolla is a minor ore of copper occurring in the oxidized parts of copper veins of Arizona and New Mexico. It is a hydrous copper silicate of the composition $CuSiO_3 2H_2O$. It occurs in compact masses with a specific gravity of 2 to 2.4, and a hardness of 2 to 4. The color is green to bluish. It was used as a green pigment by the ancient Greeks.

Atacamite is an ore of copper found in Bolivia, Australia, and Arizona. The mineral is a copper chloride with copper hydroxide, $CuCl_2 \cdot 3Cu(OH)_2$, containing 14.9 per cent of copper, 55.8 per cent of cupric oxide, and 16.6 per cent of chlorine. It is generally found in confused crystalline aggregates, fibrous, or granular. The hardness is 3 to 3.5, and the specific gravity is 3.75. The color may be various shades of green. See also Bornite.

**Copper-silicon alloys.** Silicon up to 6.7 per cent is soluble in copper, and forms hard, strong alloys very resistant to corrosion. But above 3 per cent of silicon the alloys are too hard for most uses. Copper-silicon alloys are employed for springs. Manganese up to about 1 per cent may be added to improve the working qualities, and the ratio of silicon to manganese is kept at 3 to 1. When hard-drawn these alloys have tensile strengths up to 155,000 lb. per sq. in. Webert alloy, of the American Brass Company, contains small amounts of silicon and manganese, used for pressure die castings. The tensile

strength is 85,000 lb. per sq. in. Arcoloy, of the American Radiator Company, is a casting alloy containing 97.25 per cent of copper, 2.63 silicon, 0.12 iron, and 0.01 phosphorus. See Silicon bronze.

**Copper sponge.** A porous copper made by mixing copper powder with a volatile nonmetallic substance, pressing, and heating in a hydrogen atmosphere at 900 to 1000°C. The volatile matter is expelled, and the copper particles sinter together. The sponge is then saturated with lead by immersion in molten lead in a vacuum. Copper sponge is used for machine bearings.

**Copper steel.** Steel containing about 0.25 per cent of copper and very low carbon, employed for construction work where mild resistance to corrosion is needed and where the cost of the higher resistant chromium steels is not warranted. It is employed in sheet form for culverts, ducts, and for such manufacturing purposes as for washing-machine boilers, and for pipes. The copper neutralizes the corroding influence of the sulphur in the steel, and also aids in the formation of a fine-grained oxide which retards further corrosion. Molybdenum in small quantities may also be added to give additional corrosion resistance. The percentage of copper may be raised to 0.40 when about 0.05 per cent of molybdenum is added. Toncan iron, produced by the Republic Steel Corporation, has this composition. The tensile strength of Toncan iron is 40,000 to 48,000 lb. per sq. in., elongation 32 to 40 per cent, and weight 0.283 lb. per cu. in. Copper is not added to high-carbon steels because it causes brittleness and hot-shortness. When the carbon content is low, the metal is in reality a Copper iron. The copper-bearing iron specified for culverts by the A.S.T.M. contains not more than 0.10 per cent of carbon, manganese, phosphorus, sulphur, and silicon as impurities, and not less than 0.20 per cent of copper. The corrosion-resistant copper iron produced by the Vereinigte Stahlwerke, A.G., under the name of Resista, contains not over 0.10 per cent of carbon with 0.10 per cent of phosphorus. The tensile strength is up to 85,000 lb. per sq. in. with elongation 20 per cent. Copper-bearing steels are marketed under various trade names. Copperoid is a copper-

bearing steel of the Youngstown Sheet and Tube Company. Cop-R-Loy is a low-carbon copper steel of the Wheeling Steel Corporation. Apolloy is a copper iron of the Apollo Steel Company containing 0.25 per cent copper and 0.08 carbon. Gohi iron, of the Newport Rolling Mill Company, is an open-hearth iron containing not over 0.125 per cent of carbon, manganese, sulphur, phosphorus, and other impurities, with a small percentage of copper. The rust-resistant quality results from the purity of the iron as well as from the added copper. Newaloy is a copper-bearing steel of the Newton Steel Company. Lyonore metal was an open-hearth steel containing 0.20 per cent of copper marketed by the Lyon Conklin Company, but it now contains chromium and nickel. Copper-Clude is a name given by Spang, Chalfant and Company, Inc., to copper steel used for water pipe. Beth-Cu-Loy is copper-bearing steel sheet of the Bethlehem Steel Company. Yoloy, of the Youngstown Sheet and Tube Company, is a high-tensile strength, corrosion-resistant structural steel with 1 per cent copper, 2 nickel, and up to 0.20 carbon. The tensile strength is up to 90,000 lb. per sq. in. with elongation of 30 per cent. From 0.5 to 1.5 per cent of copper is also added to some low alloy steels to give better drawing characteristics. It also gives a higher fatigue limit. Copper graphitizes the free carbides.

**Cordage.** A general term for the flexible string or line of twisted fibers used for wrapping, baling, power transmission, and hauling. Cordage fibers are any materials used for making ropes, cables, twine, and cord. Twine is cordage less than $\frac{3}{16}$ in. in diameter, and composed of two or more rovings twisted together. Rope is cordage made by twisting several yarns into strands, and then twisting the strands into a line. A cable is a strong rope, usually referring to the larger sizes of special construction. Cord is an indefinite term for twine, but is more specifically the soft cotton twines used for wrapping. Manila hemp is the most widely used cordage fiber for ropes of all kinds. Sisal hemp is used in the cheaper grades of cordage. Other fibers are also employed, and Russian hemp is considered as a superior material for strong ropes. Untarred hemp rope is

used for elevator ropes, and tarred hemp is used for ship rigging, but modern marine rope is almost entirely of Manila fiber. Sunn hemp is a weaker fiber. About 50 per cent of American strong cordage is from Manila hemp, and 28 per cent from sisal. Most industrial rope is made in three strand, and may be hard lay, medium lay, or soft lay. Cotton is employed for the weak "cords" and "strings" used for wrapping light packages. Most of the Binder twine is made from sisal hemp. India twine is made from jute. Seaming twines are made of linen. Seine twine is a three-strand cotton twine with 2 to 56 plies per strand. See Hemp. Sisal hemp, Manila hemp, Sunn hemp, Jute.

**Core oils.** Liquid binders used for sand cores in foundry work. The binder should add strength to the core, and should burn out after the metal is poured, so that the sand core will collapse. Linseed oil is claimed to be the best binder, but it is expensive for ordinary use. Core oils are usually composed of linseed oil mixed with cheaper vegetable oils or with mineral oils. In some cases fish oil or rosin oil is also used. Molasses, dextrin, and sulphite liquor may be included in prepared core oils. The specifications recommended by the American Foundrymen's Association are: raw linseed oil, 50 per cent; rosin, H grade or better, 25 per cent; water-white kerosene, 25 per cent. There should be no fish oil adulteration. A good core oil should have a specific gravity of 0.9368 maximum at 60°F., a flash point of 165 to 200°F., a Saybolt viscosity of 155 maximum, and an iodine number of 154 minimum. It should have a light amber color. However, any drying oil, or semidrying oil can be used to replace part or all of the linseed oil. Perilla oil and corn oil may be used. Core oils of linseed and soybean oil mixtures have good strength. Truline is a resinous core binder marketed by the Hercules Powder Company in powder form. Glutrin, of the Robeson Process Company, is a core oil obtained as a by-product of the sulphite paper industry. It carries the vegetable resins from the wood pulp.

**Cork.** The thick, spongy bark of a species of oak tree, *Quercus suber*, native to Spain and Portugal. It is used for bottle stoppers, insulation, vibration pads, and floats for nets and

rafts. The scrap cuttings from the bottle-cork industry are used largely for refrigerator insulation, packing for the transportation of fruits, and for the manufacture of linoleum and other materials. When marketed as Granulated cork, this material usually comes in sizes of 1/2 in. and No. 8 mesh. Cork is also used natural or in the form of pressed compositions for gaskets, oil retainers, roll coverings, polishing wheels, and many other things. The material has a cellular structure with more than 50 per cent of the volume in air cells. However, because of a lack of capillarity, it does not absorb moisture. When dried, cork is light, porous, easily compressed, and very elastic. The cell structure is peculiar, and each cell is in contact with 14 neighboring cells. Cork is one of the lightest of solid substances, the specific gravity being 0.15 to 0.20. It also has low thermal conductivity, and is valued as a heat insulator in buildings and in refrigerators. Charring begins at 250°F., but it ignites only in contact with flame. The cork tree grows to a height of about 30 ft. After it has attained the age of about 25 years it can be barked in the summer, and this barking is repeated every 8 or 10 years. The thickness of the bark varies from 1/2 to 2 in. The quality of the cork improves with the age of the tree, and if properly barked a tree will live for 150 years or more.

**Corkboard.** Construction board made from cork by compressing the granulated cork and subjecting it to heat so that the particles cement themselves together. It is employed for insulating walls and ceilings against heat or cold, and is also a sound insulator. Corkboard produced by the Armstrong Cork Company is marketed in sheets in thicknesses from 1 to 6 in. The weight is from 6 to 10 lb. per cu. ft. depending upon the binder and the compression. The heat conductivity is 0.304 B.t.u. per hr. per bd. ft. for 1°F. difference in temperature between the sides, or about one-third that of wood. Corkboard retains the properties of cork, being cellular, but without capillarity or tendency to absorb moisture. Novoid corkboard is marketed by the Cork Import Corporation. It has large and small granules tightly packed to leave no air spaces. Corinco

corkboard is produced by the Cork Insulation Company. Cork tile is made from cork shavings compressed and baked in molds, the natural gum in the cork being sufficient to act as a binder. Linotile is the trade name of the Armstrong Cork Company for a resilient tile made of powdered cork, oxidized oils, and color pigments. Joinite, of L. Mundet & Son, Inc., is a corkboard for use under machinery to deaden vibration and noise. Corkoustic is a sound-absorbent corkboard made by the Armstrong Cork Company for walls and ceilings. It has a sound-absorbing coefficient of 0.30 as compared with 0.032 for brick walls.

**Corn oil.** Known also as Maize oil. A bright-yellow oil obtained from the seeds of the maize or corn plant, *Zea mays*, and used in cutting oils, in core oils, and leather belt dressings. It is classed as a semidrying oil, having better drying properties than cottonseed oil. The iodine value is about 120, and the specific gravity is 0.920 to 0.925. Corn oil is also edible and is used as an adulterant of other edible oils. The commercial oil comes from the germ portion of the grain, which contains 20 per cent of oil, and is a by-product in the manufacture of cornstarch and glucose, or obtained from the vats in the manufacture of alcohol, although the latter is different in characteristics from the expressed oil.

**Corrosion-resistant alloys.** Any metals offering resistance to corrosion, such as the alloys of the noble metals, the stainless irons and steels, and also copper alloys containing nickel, silicon, and other elements that add to the corrosion resistance, are "corrosion resistant," but industrially the term usually refers to the alloys having chromium as a base, and alloyed with iron, nickel, cobalt, with sometimes copper, and sometimes small quantities of tungsten, molybdenum, or other elements. The chromium and nickel are the chief constituents, the other metals usually being added to give other properties, such as hardness, toughness, or lower cost. In steels used for oil-refining equipment, up to 1 per cent of molybdenum may be included for resistance to hot oils. Lebanon No. 34, for resistance to sulphuric and hydrochloric acids, has 20 per cent chromium, 30 nickel, 3.25 molybdenum, 5 copper, 3.25 silicon. The tensile

strength is 72,000 lb. per sq. in. and elongation 45 per cent. One grade of Midvaloy, of the Midvale Company, contains 60 per cent nickel, 10 chromium, 2 tungsten, and 1.5 manganese. When cast, this alloy has a tensile strength of 65,000 lb. per sq. in. and elongation 24 per cent. Delhi rustless iron, of the Ludlum Steel Company, contains 18 per cent of chromium, 1.5 silicon, and not more than 0.08 carbon. It will withstand temperatures up to 1600°F. without scaling, and has a tensile strength up to 110,000 lb. per sq. in.

Borcher's metal is a name referring to a group of acid-resistant alloys high in chromium. One grade has 30 per cent of chromium, 35 cobalt, and 35 nickel. Another grade contains 36 per cent of chromium, 60 iron, and 4 molybdenum. The commercial corrosion-resistant alloys are marketed under a variety of trade names. See Illium and Hastelloy. Some of these special alloys are complex. Sideraphite is an iron alloy containing a high percentage of nickel, with copper, tungsten, and aluminum. See Cromal. Noncorrodite is a chromium steel for castings, produced by the Millbury Steel Foundry Company. Barberite, of the Barber Asphalt Company, is a copper-base alloy with 88.5 per cent copper, 5 nickel, 5 tin, and 1.5 silicon. The silicon irons, containing high percentages of silicon, may also be classed as a group of corrosion-resistant alloys. The nickel-silicon irons are likewise corrosion resistant. See Stainless steel, Chromium-nickel steel, Nickel-molybdenum iron, Copper steel, Cupro-nickel.

**Corundum.** A crystalline mineral used as an abrasive. It is an oxide of aluminum, $Al_2O_3$, and is found in India, Asia Minor, and South Africa. The finest corundum, known as premium ore, is the material left after the gem pickers have sorted for gem stones. The hardness is about 8.8, specific gravity about 4, and it has a high refractive index, next to the diamond in the passage of X-rays. When pure it is colorless, but it usually contains metallic oxides. There are three grades, according to the crystal size and alumina content. The word is Hindu and was first applied to gem stones, but is now applied to the opaque stones used for abrasive purposes. The Ruby is a red corundum

with chromic oxide. The Sapphire is a blue variety containing titanic oxide; the Oriental topaz is a yellow corundum containing ferric oxide. Corundum in the form of off-color rubies is employed for pivot bearings in watches. Artificial corundum for use as an abrasive is now made on a large scale and sold under various trade names. See Aluminum oxide.

**Cotton.** The white fiber of the calyx, or blossom, of the cotton plant, which belongs to the Mallow family and is abundant in warm climates. It has a very wide variety of uses for making fabrics, cordage, padding, and for producing cellulose for plastics, artificial silk, and explosives. There are many varieties of the plant, yielding fibers of varying lengths, whiteness, and silkiness. The diameter of the fibers varies from 0.0006 to 0.0009 in. The most noted classes are: Sea Island, *Gossypium barbadense;* Egyptian; American upland, *G. hirsutum;* Brazilian; Arabian; and Nanking. The world production of cotton usually reaches 23,000,000 bales of 478 lb. each, 60 per cent being produced in the United States. India, Egypt, and China are also large producers. The American domestic cottons are upland, long-staple upland, American-Egyptian, and Sea Island. The short-staple upland is under 1⅛ in. in length and can be spun only into coarse and medium yarns, but is the most widely grown cotton. Long-staple upland is from 1⅛ to 1⅜ in. in length. Sea Island cotton, grown best in tropical countries, is the longest, finest, and silkiest of the fibers. Its length varies from 1¼ to 2½ in. American-Egyptian cotton, with an average length of 1⅝ in., is used extensively for automobile tire fabrics. True Egyptian, or Maco, cotton is second in quality to Sea Island. It has a long fiber, a fine luster, and great strength. It also has a remarkable twist, which makes a strong, fine yarn. Peruvian cotton, from *G. acuminatum,* is also of fine quality, but the supply is limited. Sea Island cotton has a fiber as fine as 0.0002 in. as compared with 0.001 in. for the Indian cotton which is among the coarsest.

The number, or "count," of commercial cotton yarns indicates the number of 840-yd. hanks to the pound; No. 10 cotton contains 8,400 yd. to the pound. Cotton yarn has only about

20 per cent of the tensile strength of the fibers of which it is composed. Absorbent cotton is cotton fiber that has been thoroughly cleaned and the natural wax removed with a solvent such as ether. It is very absorbent and will hold water. Cotton batting is raw cotton carded into highly matted sheets, and put up usually in rolls. It is much used for padding purposes. Cotton waste, used in machine shops for wiping, comes from the combers, usually in mixed colors.

Cotton fabrics are made in many types of weave and many weights, from the light, semitransparent Voile, made of two-ply hard-twisted yarns, and Batiste, a fine, plain-woven fabric, to the coarse and heavy canvas and duck. They may have printed designs, as in Calico, or have yarn-dyed plain stripes, as in Gingham, or have woven figures, as in Madras. All of these are plain woven. Poplin is a lateral-ribbed fabric; Rep has a rib produced by heavy warp yarns; Twill is a fabric in which the threads form diagonal lines; Crash is a rough-texture fabric with effects produced by novelty yarns; Cashmere is a soft, loose-woven fabric made to imitate mixed woolens; Charmeuse in the cotton industry is a soft, fine, satin-weave fabric of Egyptian cotton used industrially as a lining material.

**Cottonseed oil.** The most common of all vegetable oils, with more than a billion pounds produced annually in the United States. It is used primarily as a food oil, but it also has a wide industrial use. It is used to mix with and to adulterate mineral and vegetable oils employed as lubricants, cutting oils, quenching oils, and drying oils. It is also made into blown oils. See Blown oils. Cottonseed oil is expressed from the seeds of the cotton plant, *Gossypium*. The seed is separated from the fiber by means of a toothed ginning machine, and is a by-product of the cotton textile industries. See Cotton. When the seeds are crushed whole, the oil is dark in color and requires careful refining. The American practice is to hull the seeds before crushing. The oil is colorless, nearly odorless, and has a specific gravity of 0.915 to 0.921. Upland cotton seed contains about 24 per cent of oil, which is largely composed of palmitic, linoleic, and oleic acids. The residue is caked and sold as a cattle feed.

The American oil has an iodine value up to 110. Egyptian and Indian oils are inferior in color, and the Indian oil has a fishy odor and a fluorescence. Although much used as a food, cottonseed oil is devoid of the vitamin food accessories. See Hydrogenated oils. The oils are refined with a solution of caustic soda. Cottonseed oil stearin is the solid product obtained by chilling the oil and filtering out the solid portion. It has an iodine value between 85 and 100. Winter-yellow cottonseed oil is the expressed oil after the stearin has been removed.

**Cottonwood.** The wood of the large trees *Populus monilifera*, *Populus deltoides*, and several other species, of the United States and Canada. It is a soft wood of a yellowish-white color and a fine, open grain. It is sometimes called poplar, or Carolina poplar. The weight is about 30 lb. per cu. ft. The wood is easy to work, but is not strong and is likely to warp. It is used for packing boxes, paneling, and general carpentry. The *Populus deltoides*, or Eastern Cottonwood, used in paneling, has a specific gravity when kiln dried of 0.43, has a compressive strength perpendicular to the grain of 650 lb. per sq. in., and a shearing strength parallel to the grain of 660 lb. per sq. in. This wood comes from the lower Mississippi Valley. Black cottonwood is from the tree *P. trichocarpa*, of the Pacific Coast. Balsam poplar is from the tree *P. balsamifera*, of the Northeastern States. The name cottonwood is also applied to the wood of the tree *Bombax malabaricum*, native to India, Burma, and Ceylon. It is whitish in color, soft, and weighs about 28 lb. per cu. ft. It has the same general characteristics.

**Creosote.** Also called Dead oil and Pitch oil. A yellowish, poisonous oily liquid obtained from the distillation of coal tar. It has the odor of carbolic acid. The specific gravity is 1.07. The crude Creosote oil is used as a wood preservative and as a harsh disinfectant. The purified material, Cresylic acid or Cresol, is a mixture of the three cresols obtained in the distillation, ortho, meta, and para. It is a colorless or yellowish liquid of the composition $CH_3C_6H_4OH$, with specific gravity of 1.042, and solidifying at 11°C. It is used in making synthetic resins in place of phenol. In combination with phosphoric acid it forms

Cresyl phosphate, or "Lindol," used in lacquers as a substitute for camphor. Cresylic acid is not soluble in water, but when mixed with soap is easily soluble and is used in cutting oils as a disinfectant. Creosote is also obtained in the distillation of wood tar, and is then a yellowish liquid with a smoky odor, a mixture of phenols and derivatives. Cresylic acid and the crude Creosote oil owe their preservative qualities to the poisonous Acridine, which may be separated out and used as an insecticide. No-D-K is a concentrated hardwood creosote oil of the Tennessee Eastman Corporation. Since the distilling temperature is above 200°C., it is not driven off by the leach of the sun when used as a preservative. The distillation of wood also produces Methyl acetate, gas, and charcoal. See Tec-char. Methyl acetate is a colorless, sweet-smelling liquid of the composition $CH_3CO_2{\cdot}CH_3$, used as a solvent for lacquers. The specific gravity is 0.924, and boiling point 54°C.

**Crinoline.** A stiff fabric of very open weave, made of coarse cotton yarns and heavily sized. The weave is plain. It was originally made of horsehair and linen, and hence its name. Crinoline is bleached, or is dyed in plain colors, and is used industrially as a supporting medium for parts made of waxes or composition, or where a stiff coarse fabric is needed.

**Crocus.** A named applied to mineral powders of a deep yellow, brown, or red color used as pigments or for polishing. Polishing crocus is chiefly red ferric oxide. See Rouge. The grains are hard and sharp; for polishing they are made up with grease. Crocus cloth is cloth coated with red iron oxide, marketed in sheets, and used for polishing metals.

**Crotonaldehyde.** A straw-colored, inflammable, mobile liquid of the composition $CH_3{\cdot}CH{:}CH{\cdot}CHO$, with specific gravity of 0.852 to 0.858, and boiling point of 99 to 104°C. It is used as a solvent for resins, gums, and rubber. It is soluble in alcohol, benzol, and naphtha. Crotonaldehyde has a pungent, suffocating odor and lachrymatory power, and is an effective war gas with no toxic quality. One pound of crotonaldehyde per million cubic feet of air will awaken a sleeping person, and

it is thus used in city gas mains as a warning agent on the escape of poisonous fuel gases. It is also used in the tanning of leather.

**Crown glass.** A white glass, known as Soda-lime glass, employed for windows. A typical composition is 72 per cent of $SiO_2$, 13 of CaO, and 15 per cent of $Na_2O$. The glass derives its name from the circular crowning method of making the sheets. The superior surface of crown glass is partly attributed to the polishing. See Glass.

**Crucible steel.** A steel made by melting small pieces of wrought iron or ingot iron in a crucible with charcoal and ferromanganese. In England shear steel and blister steel are used. The crucibles usually hold 80 to 100 lb. of iron, and are sealed with a cover and placed in a furnace. The slag separates by gravity from the molten metal, and the oxides combine with the carbon and manganese and boil off. After melting it is held at a high temperature for some time with no boiling. The slag is removed with an iron rod, and the metal run into cast-iron molds, which have been coated with soot and preheated. If large ingots are desired, the contents of several crucibles are poured into a large ladle. The pouring of the steel into the molds is known as "teeming." The ingots are reheated and hammered, drawn, and rolled into bars. The crucible process is used for making tool steels as it permits a high degree of control and reduces the phosphorus and sulphur to a minimum.

**Crushed stone.** Stone that has been quarried, crushed, and graded for use in construction work. Crushed stone is the common material for concrete aggregate. It differs from sand and gravel in having sharp edges, and also from large-sized gravel by being usually composed of only one kind of rock. Graded stone usually begins at ¼ in., and runs by various stages up to 2½ in., although larger sizes are sometimes called for. Screenings range from dust up to about ¼ in. diameter. Crushed stone in the larger sizes is used for concrete; the smaller grades are employed largely in paving.Granite granules for making hard terrazzo floors are marketed in several sizes, and in pink, green, and other natural colors.

**Cryolite.** A mineral of the composition $Na_3AlF_6$, found in commercial quantities in Greenland, and used as a flux in the electric production of aluminum, and in the making of special glasses and porcelain. It occurs in masses of a vitreous luster, colorless to white, with a hardness of 2.5. It fuses easily. Kryalith is a trade name for the synthetic cryolite marketed by the Pennsylvania Salt Manufacturing Company.

**Cumerone.** A colorless liquid of the composition $C_8H_6O$, employed in making synthetic resins. Cumerone occurs in the fraction of naphtha boiling between 165 and 175°C., and is isolated by treating with acid. The specific gravity is 1.096, and boiling point 172°C. It has a characteristic smell, is insoluble in water, and is easily attacked by oxidizing agents. Another product of a similar nature is Indene, $C_9H_8$, which is a colorless liquid boiling at 180°C., that can be oxidized and polymerized readily. The Indene resins are classed with the cumerone resins, but are lighter in color and are used in varnishes. The Cumerone resins, $C_6H_4{\cdot}CH{\cdot}O{\cdot}CH$, made by the action of sulphuric or phosphoric acids on cumerone, are distinguished by their great solubility in organic solvents and are thus valued for lacquers and varnishes. They are also used for waterproofing, in molding compounds, and in adhesives. The specific gravity of the molding resins is from 1.05 to 1.15. They have high dielectric strength. Cumar gum is a synthetic resin mixture of polymerized cumerone and indene, used in varnishes and lacquers and in adhesives. It is also called Para-cumerone, or Para-indene resin. The grades vary from a soft gum to a hard brown solid, with melting points from 5 to 140°C. Varnishes made with it are resistant to alkalies. Nevindene, of the Neville Company, is a para-cumerone-indene resin of specific gravity of 1.08 and melting point 10 to 160°C., used for compounding with rubber and Neoprene. Cumar is the name of a cumerone-indene resin of the Barrett Company.

**Cupro-nickel.** Any alloy of copper and nickel, as nickel and copper form solid solutions in all proportions. The cupro-nickel alloys were among the first used. They are ductile and malleable, are corrosion resistant, and have a maximum hardness at about 50 per cent nickel. Cupro-nickel with 2.5 per cent of nickel is

used for the driving bands of shells; 15 per cent nickel for bullet jackets and condenser tubes; and 25 per cent for coinage. The standard cupro-nickels are 5, 15, 20, and 30 per cent nickel. It is also much used as a heat-resistant material. Copel, of the Driver-Harris Company, contains 55 per cent copper and 45 nickel, and is used for resistance wire where the temperature does not exceed 800°F. Lucero, of this company, has 70 per cent of nickel and 30 copper. It is used for resistance wire and strip for temperatures up to 1100°F. The cold-worked strip has a tensile strength up to 140,000 lb. per sq. in., and is used for springs for electrical apparatus because of its low temperature coefficient.

Fifteen per cent nickel alloy can be rolled from a thickness of 1½ in. to about 0.040 in. without intermediate annealing. Nickel whitens copper and gives the alloys a characteristic pinkish-white color sometimes called yellowish, which can be whitened by the addition of small amounts of cobalt. At least 10 per cent of nickel is needed to obtain a nickel-white color; this amount gives high corrosion resistance. When color is important, the alloys should not contain zinc because of the change in color by dezincification, especially in hot applications. Aluminum is also used as a whitener and hardener. An old formula for a silvery-white alloy for silverware, called Minargent, called for 100 parts of copper, 70 nickel, 6 antimony, and 2 aluminum. An alloy of 60 per cent nickel and 40 copper weighs 0.320 lb. per cu. in. Super-nickel is a name given by the American Brass Company to an alloy of 70 per cent copper and 30 nickel, used for condenser tubes. It is corrosion resistant and has a tensile strength of 75,000 lb. per sq. in. with elongation of 5 per cent. The white alloy of the Scovill Manufacturing Company known as Adnic, used for valve diaphragms and parts for chemical machinery, has 70 per cent of copper, 29 nickel, and 1 tin. When hard-drawn, Adnic has a tensile strength of 113,000 lb. per sq. in. and elongation of 10 per cent. The hot-rolled rod has a strength of 65,000 lb. per sq. in. and elongation of 45 per cent. Small amounts of silicon added to cupro-nickel form a nickel-silicide which gives a Hardenable copper, which is the ancient tool material of the Incas. The alloy is capable of

being hardened by heat treatment. An alloy of this type, marketed by the American Brass Company under the name of Tempaloy, contains about 95 per cent of copper, 4 nickel, and 1 silicon. It is hard and strong, and can be forged or cold rolled. Annealing by heating throws the nickel silicide into solid solution and produces a soft and ductile metal, which again can be hardened by holding at a temperature of 450°C. for several hours. The tensile strength is from 50,000 to 150,000 lb. per sq. in. with hardness above 200 Brinell. This class of alloy, however, is not generally grouped with the cupro-nickels.

Small amounts of manganese and iron may also be added to cupro-nickel to harden and strengthen the alloy. Davis metal, used by the Chapman Valve Manufacturing Company for valves and fittings, contains 67 per cent copper, 29 nickel, 2 iron, 1.5 manganese, and 0.5 carbon and silicon. The castings are hard and corrosion resistant. Cufenium, a white alloy used as a base metal in tableware, contains 72 per cent copper, 22 nickel, and 6 iron. Some chromium may be added for added corrosion resistance. Everbrite, of the American Manganese Bronze Company, has 60 per cent copper, 30 nickel, 3 iron, 3 silicon, and 3 chromium. It is white in color, has a tensile strength, cast, of 75,000 lb. per sq. in., elongation of 14 per cent, and Brinell hardness of 170. Cataract metal, of the Niagara Falls Smelting and Refining Corporation, is the name of a series of cupro-nickel alloys containing small amounts of other elements. Federal specifications for cupro-nickel call for a minimum of 65 per cent of copper and 25 nickel with other elements allowable, under the name of Copper-nickel alloy. This name is also used for cupro-nickel slabs and shot used for adding nickel to brasses and bronzes. The Copper-nickel alloy of H. Kramer & Company is in two grades of 50 per cent nickel and 25 per cent nickel. See also Nickel brass and Nickel bronze.

**Curupay.** The wood of the tree *Piptadenia cebil*, native to Argentina, Paraguay, and Brazil, employed locally for construction and used as an ornamental hardwood. It is very hard, weighs 74 lb. per cu. ft., has a reddish color, and a handsome, wavy grain.

**Cutting alloys.** Nonferrous alloys used for cutting tools, as distinguished from alloy steels, although some may contain iron and be allied to super high-speed steels. They may have a base of nickel or cobalt and usually contain tungsten. An early alloy of this type, Cooperite, contained 80 per cent nickel, 14 tungsten, 6 zirconium, and 14 tungsten, or less tungsten with some silicon and molybdenum. An English cutting alloy, marketed by Samuel Osborne & Company, Ltd., under the name of S.O.B.V. cutting alloy, contains high percentages of chromium, cobalt, tungsten, and iron, with some vanadium and molybdenum, and is really a super high-speed steel. Stellite, of the Haynes Stellite Company, is made in various grades for cutting tools, hard-facing valves, rock bits, and crusher rolls. It is typical of the nonferrous hard metals, and the cutting properties are inherent in the alloy and are not produced by heat treatment. Stellite contains from 40 to 75 per cent of cobalt, 15 to 35 chromium, 10 to 25 tungsten, about 2 per cent of carbon, and small amounts of iron and molybdenum. It retains its hardness at red heat. It is silvery white in color, has a hardness of about 570 Brinell, and a tensile strength up to 130,000 lb. per sq. in. J-metal is a special high grade. Rexalloy, of the Crucible Steel Company, is a cast cutting alloy of cobalt, chromium, and tungsten, which will retain its cutting edge at red heat.

**Cutting oils.** Oils employed for lubricating metals being machined. They are usually heavy oils or compounds distinguished from the thin water-soluble oils used for flooding the work with the chief object of keeping it cool. Lard oil is generally recognized as the best cutting oil, but is now seldom used alone because of its cost. It is mixed with mineral and vegetable oils, or with hydrogenated oils. For cutting brass lard oil was formerly much used, but an emulsion of oil in soapy water is often employed. Carbon tetrachloride mixed with turpentine in the proportion of 3 to 1 is used for hard chromium steels. Mixtures of oil, turpentine, and kerosene are also used for cutting hard steels. A typical oil for screw cutting is made with 75 per cent of paraffin oil and 25 per cent cottonseed oil. For fine cutting of threads white lead mixed with a heavy oil

is used. Mixtures of various oils and greases, called cutting compounds, are marketed under trade names and may also contain disinfectants. Small amounts of cresol, or 2 per cent of carbolic acid, may be employed for this purpose. The object of the cutting oil is to act as a lubricant between the tool and the work, decreasing the friction. It also carries off much of the heat, enabling the tool to stand up longer under the cutting action. Aquadag, a solution of 22 per cent of colloidal graphite in water, marketed by the Acheson Colloids Corporation, is used as a cutting lubricant. See also Soluble oils.

**Cyanogen.** A colorless gas with a pungent odor, poisonous, and inflammable, and used in chemical warfare as a poison gas. The composition is $C_2N_2$, and it is made by the addition of a solution of potassium cyanide to a solution of copper sulphate. The specific gravity is 1.806, and the liquefying point 21°C. See Lethal gases. Cyanogen chloride is a colorless, poisonous liquid of the composition CNCl, employed as a lachrymatory war gas. The boiling point is 13°C., and the solidifying point is −5°C. It is soluble in water and alcohol. It is made by treating hydrocyanic acid with chlorine. It was called by the French name of Manguinite and, when mixed with arsenic trichloride, was called Vitrite. The Italian war gas Campillit is Cyanogen bromide, CNBr. It is a white crystalline solid of a specific gravity of 2.02 melting at 52°C. and boiling at 61.3°C. The fumes are highly toxic, paralyzing the nerve centers.

**Cylinder iron.** A general name given to cast irons used for making engine cylinders, pistons, and piston rings. A plain cylinder iron for automotive engines contains 3 to 3.25 per cent of total carbon, 0.40 to 0.75 manganese, 2 to 2.25 silicon, a maximum of 0.12 phosphorus, and a maximum of 0.12 sulphur. The alloy cylinder iron for the same engine contains 3 to 3.5 per cent carbon, 0.50 to 0.80 manganese, 1.75 to 2.25 silicon, 1 to 1.5 nickel, with sometimes small amounts of chromium. Cylinder irons are very hard, close grained, and free from spots or holes. Ordinary low-silicon iron, with 1 to 1.75 per cent of silicon, chills in thin sections, and nickel is added to overcome this. An outboard engine cylinder iron has 2

per cent of nickel and 0.50 chromium. It casts easily and has good wear resistance. Copper additions increase the heat conductivity. A truck cylinder block iron containing 3 per cent total carbon, 0.75 combined carbon, 2 silicon, 1.7 nickel, and 0.7 chromium, has a tensile strength of 38,000 lb. per sq. in. and a hardness of 229 Brinell. A locomotive cylinder iron for 200 lb. steam pressure, has 1.25 per cent nickel, 1 silicon, 0.60 to 1.0 manganese, and 3 per cent total carbon. See Nickel cast iron.

**Cypress.** The wood of the cypress tree, *Cupressus sempervirens*, of Europe, and of other trees of the same genus of Europe and North America. It is a light, soft wood but is durable. It is light brown in color and has a pleasant, aromatic odor. It is used for furniture, chests, doors, and general construction. The wood known as cypress, Marsh cypress, Red cypress, or Bald cypress, in the United States is from the coniferous trees *Taxodium distichum*, and the Pond cypress, is from *Teascendens*, of the Southeastern states. It is yellowish red or pink in color, and is a soft wood with an open grain. The weight is about 37 lb. per cu. ft. It is very durable, and is valued for shingles, or for construction where resistance to weather exposure is needed. Yellow cedar is also sometimes called cypress.

**Dammar.** Also written Damar. The resin from various species of trees of the genus *Shorea*, *Balanocarpus*, and *Hopea*, of southern Asia and the East Indies, but also applied to the resins of other trees, especially from the *Dammara orientalis*, of the Malay Peninsula, now known to be the same tree as the *Agatha alba*, the source of Manila copal. This tree gives the copal known as White dammar. In the Philippines the tree is called Almacido, and the gum, Manila copal. There is no dividing line between the dammars and the copals, and dammar may be considered as a variety of copal. Dammar is used in varnishes and lacquers, in adhesives, and in coatings. The usual specific gravity is 1.04 to 1.12, and melting point up to 120°C. To obtain the resin the trees are tapped, and the solidified gum collected after several months. The best resins are from deposits at the bases of the trees, known as fossil resins. Dammar

is classified according to the size and the color, the best grades being colorless and in large lumps. The resin is soluble in alcohol and in turpentine; the Batavia and Singapore dammars are soluble in chlorinated compounds and in hydrocarbons. Black dammar is from the tree *Canarium strictum*, of India, and comes in black, brittle lumps, easily ground to powder. The reddish Dammar sengai is also from a species of *Canarium*. Cat's-eye dammar is a high-grade pale-colored resin from a species of *Hopea*. The plentiful Dammar Penak is from the Malayan tree *Balanocarpus heimii*. The *Shorea* resins are usually dark in color. The Malayan black dammar, Dammar hitam, is from a species of *Balanocarpus*. The high-quality dammar from Batavia and Sumatra is from a species of *Hopea*. In general, the true dammars are from the *Shorea* and *Balanocarpus*, and are inferior to those approaching the copals. The average grade of true dammar does not have a melting point much higher than 100°C. Dammar is a spirit varnish resin, and gives a flexible film, but is softer and less durable than the copals. It is noted for its complete solubility in turpentine. Most of the White dammar known as Manila copal, or Manila gum, comes from Macassar. It is a semihard to hard resin, and is used in paints where resistance to wear is required, as in road-marking paints, but it is not as hard as Congo copal. See Copal.

**Degras.** A brownish fat of a faint disagreeable odor, obtained from sheep wool by washing, and used for leather dressing, as a rubber softener, for lubricating greases, and for producing lanolin. The specific gravity is about 92, and the melting point is 97 to 108°F. Lanolin is the purified grease, also known as Lanain and as Lanum. Paralan is the trade name of a slushing oil having a lanolin base marketed by the American Lanolin Corporation. Moellon degras is a by-product of the chamois leather industry. The skins are impregnated with fish oil; when the tanning is complete, the skins are soaked in warm water and the excess oil pressed out to form the moellon degras.

**Delta metal.** A brass containing iron, with small amounts of lead, manganese, and phosphorus, and first marketed by

Alexander Dick in 1883 as a substitute for more expensive hard bronzes. The lead, manganese, and iron usually do not exceed 1 per cent. Iron above 0.35 per cent forms a separate iron-rich constituent which is stable and gives high strength to the alloy. Manganese helps to absorb the iron and also hardens the metal. Lead aids the machining qualities, and the phosphorus deoxidizes the alloy. Delta metal produces sound castings and is also adapted for forging. Cast Delta metal has a tensile strength of 45,000 lb. per sq. in. and an elongation of 10 per cent. The 60–40 brasses are now often modified with iron and manganese. See also Aich's metal, Muntz metal, and Manganese bronze.

**Denaturants.** Substances used for mixing with ethyl alcohol to be employed for industrial purposes to prevent the use of the alcohol as a beverage and to make it tax free under the Tax Free Industrial Alcohol Act. Some of the denaturants are merely ill tasting; others are poisonous. In all cases they are difficult to remove by ordinary distillation. The usual denaturants are Methyl alcohol, pyridine, benzene, kerosene, and pine oil. One or several of these may be employed, but denaturants must be approved by the Bureau of Internal Revenue. Completely denatured alcohol is a term used to designate alcohol containing poisonous ingredients, and is used only for antifreeze, fuels, and lacquers, but not in contact with the human body. Special denatured alcohol is alcohol containing material authorized for special uses, such as pine oil for hair tonics. Many approved denaturants are marketed under trade names. Denol is the name of a mixture of primary and secondary aliphatic higher alcohols. Agadite is a compounded petroleum product. Hydronol is a hydrogenated organic product.

**Denim.** A heavy, twill-woven cotton fabric, yarn-dyed usually in either light blue or dark brown. It is widely used for workmen's overalls, jumpers, and work shirts, industrially where a tough fabric is needed. Art denim, in plain colors or woven with small figures, is used for upholstery. The quality of denim is denoted by its weight in ounces per yard, and by the count of the yarn.

**Dextrin.** Also called Amylin. A group of compounds with the same empirical formula as starch $(C_6H_{10}O_5)_x$, but believed to have a smaller value of $x$. They have strong adhesive properties and are used as adhesive pastes, particularly for envelopes and postage stamps, for adulterating gum arabic, in pyrotechnic compositions, and as fillers for cloth. Dextrin is a white, amorphous powder, tasteless and odorless. It dissolves in an equal amount of water to form a sirupy liquid, and is thus distinguished from starch. Dextrin is made by moistening starch or flour with a mixture of dilute nitric and hydrochloric acids, and then exposing to a temperature of 100 to 125°C. Dextrin varies in grade chiefly due to differences in the starch from which it is made. British gum is a type of dextrin which gives high tack for paste use. See also Starch.

**Diamond.** A highly transparent and exceedingly hard crystalline stone of almost pure carbon. When pure it is colorless but often shows tints of white, gray, blue, yellow, or green. It is the hardest known substance, and is placed as 10 on the Moh hardness scale. The diamond always occurs in crystals in the cubical system and has a specific gravity of 3.521. It has been valued from ancient times as a gem stone, but is also used extensively as an abrasive, for cutting tools, and for dies for drawing wire. These Industrial diamonds are diamonds that are too hard or too cross-grained for good jewel cutting. Jewel diamonds have the formation in regular layers, while industrial diamonds are "grown" in all directions. Technically these are called "feinig" and "naetig." Ballas diamonds, valued for industrial drilling, are formed with the crystallization starting from one central point. The stones thus formed do not crack in the tool as easily as those with larger formation. See Carbons. The stones for industrial purposes are also the fragments or the "bort" unsuitable for cutting into gems. See Bort. The value of diamonds is determined by their size, color, purity, and freedom from flaws. The weight is measured in carats, a carat being 200 mg. Diamond splinters as small as $\frac{1}{500}$ carat are cut and faceted. The most valued for gems are the blue-white. A faint straw color detracts from the value, but deep shades of yellow,

red, green, or blue are prized. Most of the diamonds come from South Africa, Brazil, and India. They have been found in only one place in the United States, in Pike County, Arkansas. The famous Kohinoor diamond weighed originally 793 carats, and the Jonkers diamond from South Africa was a blue-white stone which weighed 726 carats. Diamond dust is a powder obtained by crushing bort, or from refuse from the cutting of gem diamonds. It is used to grind hard steels, for cutting other stones, and for making Diamond wheels for grinding. For wheels and drill heads it is mixed with powdered metal and sintered into a solid mass.

**Diatomaceous earth.** A class of compact, granular or amorphous minerals composed of hydrated silica, used as an abrasive, for filtering, in metal polishes and soaps, as a filler in paints and molding plastics, and for making insulating blocks and boards. The material is not earthy, and a preferred name is Diatomite. Tripoli and kieselguhr are varieties of crystalline diatomite. The American production of the mineral is mainly in California, Nevada, and Washington. After mining, the material is crushed and calcined. When pure it is white, but with impurities it may be gray, brown, or greenish. The fine powder used as a filler is sometimes called Fossil flour. For insulating purposes, bricks or blocks are sawed from the solid or molded from the crushed material, or it may be used in pulverized form. Pure diatomite has a porosity of 90 per cent of its volume and will hold five times its volume of water. The apparent density is usually 12 to 17 lb. per cu. ft. Celite is a specially prepared diatomaceous earth produced by Johns-Manville for use in portland cement mixtures. It acts as an ultrafine aggregate and produces a plastic concrete for ornamental detail work. It also makes the concrete waterproof. Sil-O-Cel C-22, of this company, is calcined Celite, capable of withstanding temperatures up to 2000°F.; Sil-O-Cel is the natural brick cut from diatomite. It will stand temperatures up to 1600°F., and has a crushing strength of 400 lb. per sq. in. Dicalite, a diatomite marketed by the Philip Carey Company for heat-insulating cements or as a filler for walls, is a fine powder, weighing 8 to 8.5 lb. per

cu. ft. loose, and 15 to 17 lb. tamped. Superex, of Johns-Manville, is calcined diatomite bonded with asbestos fibers. It resists temperatures up to 1900°F. See also Tripoli and Kieselguhr.

**Die-casting metal.** Any alloy employed in making parts by casting in metal molds, or "dies." It may vary widely in composition and color, although all of the die-casting alloys are usually whitish. The important groups of die-casting metals are aluminum base, zinc base, magnesium base, and copper base. Lead-base alloys are also used, but mostly for casting ornaments and toys. Aluminum die-casting alloys are now largely silicon alloys with from 3 to 12 per cent of silicon, with or without copper. The latter runs from 2 to 8 per cent. Some contain nickel for better color and added toughness. A 5 per cent silicon alloy has a tensile strength of 29,000 lb. per sq. in., and elongation of 3 per cent. With 4 per cent of copper the alloy has a tensile strength of 44,000 lb. with elongation of 0.2 per cent and Brinell hardness of 75. This is Alloy 85 of the Aluminum Company of America. Additions of small quantities of tin improve machining and polishing qualities but develop hot-shortness. Aluminum-base alloy of the Milwaukee Die Casting Company, known as Ruselite, contains 94 per cent aluminum, 4 copper, and 2 per cent each of chromium and molybdenum. It has a fine white color and is resistant to corrosion and to acids. The tensile strength is 30,000 lb. per sq. in. with an elongation of 6 per cent. The same metal is also used in wrought form. An aluminum die-casting alloy of the Allied Die Casting corporation, known as Renyx, contains, in one grade, 91.5 per cent of aluminum, 4 nickel, 4 copper, and 0.5 silicon. It has good color and is resistant to corrosion. Alloy AM23O, of the Aluminum Company of America, is a magnesium alloy and contains 9 to 11 per cent aluminum, 0.5 to 1.0 silicon, and 0.10 manganese. This alloy weighs 0.066 lb. per cu. in. It has a tensile strength of 31,000 lb. per sq. in.

A typical copper-base alloy has 64 per cent of copper, 36 of zinc, and is a true brass. The tensile strength is 40,000 lb. per sq. in. A typical zinc-base alloy contains 88 per cent of zinc, 8 of tin, and 4 of copper. The tensile strength is 35,000 lb. per sq. in., and

the Brinell hardness is 55 to 65. It is quite brittle and will not withstand shocks. Aluminum, or a higher zinc content, may be employed to replace the tin. Renyx AZN, of the Allied Die Casting Corporation, contains 92 per cent zinc, 4 aluminum, 3 copper, and 0.1 manganese. Tin-base alloys are not frequently used for die castings because of the cost of tin. See also Zinc-base alloys.

**Diphenyl-chloro-arsine.** Also known as Sneezing gas, and called Blue cross during the World War. It is a solid substance having a melting point of 44°C. and a boiling point of 333°C. The composition is $(C_6H_5)_2AsCl$. Diphenyl-chloro-arsine is usually thrown in high-explosive shells, which disseminate the poison in a fine mist, to penetrate the ordinary gas mask, compelling its removal, and thus allowing more poisonous gases to be inhaled. Diphenyl-chloro-arsine affects chiefly the nose and throat, but is also a lethal poison. It is nonpersistent and therefore difficult to form in dangerous concentration. Diphenyl-amino-chloro-arsine, known as Adamsite, is a greenish granular solid of the composition $(C_6H_4)_2NHAsCl$, used as a Toxic smoke. It has a pleasant odor but burns the nose and throat. Diphenyl-cyano-arsine is a violent sneezing gas poison having the composition $(C_6H_5)_2AsCN$. Besides attacking the nose and throat the vapor causes great pain and dizziness and is lethal. Phenyl-dichlor-arsine, $C_5H_5AsCl_2$, called by the French "Sternite," is a clear viscous liquid of specific gravity 1.64 and boiling point 252°C. It forms a dense vapor 7.75 times heavier than air, which is a powerful lung irritant and vesicant. It is more toxic than phosgene. Ethyldichlorarsine, $C_2H_5AsCl_2$, called Dick gas by the Germans, is a clear oily liquid which boils at 156°C. The heavy vapor is a toxic lung irritant. See also Poison gases.

**Diphosgene.** An oily liquid of the composition $ClCOOCCl_3$, specific gravity 1.652, and boiling point 128°C., used as a lethal war gas. It was known as Green cross during the World War and is also called Superpalite and Perstoff. It has an asphyxiating odor, is a lung irritant and an intense lachrymator. The liquid attacks metals and cannot be placed in contact with them. See Lethal gases.

**Disinfectants.** Substances used for killing germs, bacteria, or spore, and thus eliminating causes of disease or bad odors in factories, warehouses, or in oils and compounds. In medicine the term Antiseptic is employed in a similar sense. Some disinfectants are also used industrially as preservatives for leather and other materials, especially chlorine and chlorine compounds. Cresol is used in cutting oils to prevent disease. Phenol is the best known disinfectant, and the germ killing power of other chemicals is usually based on a comparison with phenol. Practically all bacteria are killed in a few minutes by a 3 per cent solution of phenol in water. Creosote oil and cresylic acid are employed in emulsions in disinfecting sprays and dips. Too large a proportion of disinfectants in solutions or in the air may be injurious to workers, and advice of health officials is ordinarily obtained before use. Thymol, $C_{10}H_{13}OH$, an essential oil obtained from the thyme plant, is widely used as a disinfectant in ointments, soaps, and solutions. Formaldehyde has high germicidal power, and is used for hides and leather. See Merclor. Antiseptic atmospheres are produced by spraying chloromine-T, argyrol, or iodine.

**Divi-divi.** The dried pods of the tree *Caesalpinia coriaria*, native to tropical America, employed in tanning leather. The pods are about 3 in. long, and contain up to 45 per cent of pyrogallol tannin. It has a disadvantage in that it ferments easily and develops a red coloring matter. The best pods are the thickest and lightest in color. The commercial extract contains 25 per cent of tannin. Algarobilla, from the pods of the *C. brevifolia*, of Chile, is a similar tanning agent. Cascalote is from the pods of the tree *C. cacolaco*, of Mexico. It is the standard tanning material of Mexico. White tan, or Tari, is from the pods of the *C. digyna*, of the Far East.

**Dolomite.** A type of limestone employed in cement making, as a flux in melting iron, as a lining for basic-steel furnaces, and as a building stone. It is a carbonate of calcium and magnesium of the composition $CaMg(CO_3)_2$, occurring widely distributed in coarse, granular masses or in fine-grained compact form. The specific gravity is 3.5 to 4. It may be colorless, pink, white, gray, green, or black. For furnace linings it is calcined, but for fluxing

it is simply crushed. See Fluxing stone. Calcined dolomite is used in Germany as a water filter material under the name of Magno masse, marketed in grain sizes 0.5 to 5.0 mm.

**Doublé.** A French name given to sheet metals made in two or more layers by uniting the sheets by rolling at a high temperature. They usually consist of copper, brass, or other metal, with a thin facing of noble metal for acid resistance, or of gold or silver for appearance. Efkabimetal is a copper doublé covered with a noble metal produced by F. Kammerer, A. G. See also Gold shell, Duplex metals, Composite metals.

**Douglas fir.** The wood of the tree *Pseudotsuga taxifolia*, of the Northwestern United States and British Columbia. It is sometimes called Oregon pine, Douglas pine, Red fir, Fir, Douglas spruce, Yellow fir, and Puget Sound pine. The wood of young trees with wide growth rings is reddish brown, and is called red fir. The wood of older trees of slower growth with narrow rings is usually yellowish brown and is called yellow fir. Both woods may come from the same tree. The narrow-ringed wood is generally the stronger and heavier. Douglas fir averages below longleaf pine in weight, strength, and toughness, but above loblolly pine in strength and toughness, though below it in weight. The grain is even and close, with resinous pores less pronounced than in pitch pine. It is soft wood, and is fairly durable. The weight is 34 lb. per cu. ft. The compressive strength perpendicular to the grain is 1,300 lb. per sq. in., and shearing strength parallel to the grain 810 lb. per sq. in. Douglas fir is used for general construction work, woodenware, crossties, and where large timbers are required. The trees grow to great heights, the average being 80 to 100 ft. The stand of Douglas fir is estimated at more than 450 billion board feet, or about one-fourth of all timber in the United States.

**Drawing paper.** A heavy paper, usually buff or white in color, employed for making drawings. For mechanical drawings the buff color is preferred, as it is easier on the eyes and not so readily soiled. Drawing papers are smooth or rough, the first being hot-pressed. Good grades of drawing paper should permit

considerable erasure without destroying the appearance. Buff detail paper for pencil use is made slightly rough or grained. High-grade paper for ink work is extra hard-sized and coated. Drawing paper is marketed in rolls of widths from 30 to 72 in., and in standard sheets varying from "cap," 17 by 13 in., to "antiquarian," 52 by 31 in. The most usual drawing sheet sizes in the United States are 9 by 12 in., 12 by 18, 18 by 24, 24 by 36, and 36 by 48. Tracing paper is usually a good grade of hard transparent tissue paper in sheets and rolls, in white or buff colors. See Tracing cloth.

**Driers.** Substances used for increasing the rapidity of drying of paints and varnishes. The chief function of these driers is to absorb oxygen from the air and transfer it to the oil, thus accelerating its drying to a flexible film. They are in reality catalyzers. Driers are chiefly oxides of lead, cobalt, or manganese, such as cobalt linoleate and pyrolusite. Metallic salts of organic acids, such as aluminum resinate and aluminum palmitate, also have this property. Manganese acetate is a common paint and varnish drier. It is a pinkish crystalline powder of the composition $(CH_3COO)_2Mn \cdot 4H_2O$, soluble in water and in alcohol. Sugar of lead, used as a drier, is Lead acetate, $Pb(C_2H_3O_2)_2 \cdot 3H_2O$, a white crystalline substance. Lead oleate, $Pb(C_{18}H_{33}O_2)_2$, is a drier made by the action of oleic acid on a lead salt, and is also used in lubricants. Lead linoleate, $Pb(C_{18}H_{31}O_2)_2$, is a drier made by adding litharge to linseed oil and heating. Lead and manganese compounds together act more effectively as driers than either alone. Lead resinate adds toughness of film as well as drying power. Certain oil, such as tung oil, have inherent drying properties and are classed as drying oils, but not as driers. Solutions of driers are called liquid driers, and it is in this form that the user of the paint or varnish adds the drier. Excessive use of driers will destroy the toughness of the film and cause the paint to crack. See Drying oils.

**Drill.** A stout, twilled, cotton fabric used for lining and where a strong fabric is required. It comes bleached, unbleached, or piece-dyed. It is made in various weights, and is designated in ounces per square yard. Tan-colored drill is called Khaki.

**Drill rod.** Tool-steel round rod made to a close degree of accuracy, generally not over or under 0.0005 in. the diameter size, and usually polished. It is employed for making drills, taps, reamers, punches, or for dowel pins, shafts, and rollers. Common drill rod is of open-hearth high-carbon steel hardened by quenching in water or in oil. The usual commercial sizes are from 1½ in. in diameter down to No. 80, which is 0.0135 in. in diameter; the lengths are 1 ft. and 3 ft. The sizes are by the standard of drill gages, with about 200 different diameters. The carbon content is usually from 0.90 to 1.05 per cent, with 0.25 to 0.50 of manganese, 0.10 to 0.50 of silicon, and a maximum of 0.04 per cent of phosphorus or sulphur. It also comes in high-carbon with from 1.50 to 1.65 per cent of carbon and 0.15 to 0.35 per cent of manganese. Drill rod can also be obtained regularly in high-speed steels, and in special alloy steels for dowel pins. Some mills also furnish square rods to the same accuracy under the name of drill rod. Needle wire is round tool-steel wire used for making needles, awls, and latch pins. It comes in coils, in diameters varying by gage sizes from 0.010 to 0.105 in. Stud steel is an English name for round bar steel, hardened, scaled, and made to close limits, used for heavy pins and studs. Pin bar is small-diameter rod of casehardening steel used for dowel pins. Drill steel, for mine and quarry drills, comes in standard rounds, octagons, squares, and cruciform bars, either solid or hollow, usually in carbon steel.

**Drying oils.** Vegetable or animal oils which are easily oxidized by exposure to the atmosphere and employed in paints and varnishes. The drying of an oleo-resinous varnish takes place in two stages. First, the reducer or solvent evaporates, leaving a continuous film composed of gums and drying oil. The drying oil then is oxidized by exposure, leaving a tough, hard skin. This oxidation is hastened by metallic oxide driers, but the drying oil itself is responsible for the film. The drying power of oils is measured by their Iodine value, as their power of absorbing oxygen from the air is directly proportional to their power of absorbing iodine. The best commercial drying oil is tung oil, but linseed oil is the most common. It has high drying power and is readily available. Linseed oil alone will take seven days to dry,

but can be quickened to a few hours by the addition of driers. Other drying oils are stillingia oil, soybean oil, and N'gart oil. The last is from the seed nuts of a climbing plant of Africa, and is equal in drying power to linseed oil. Lallemantia oil, obtained from the seeds of the *Lallementia iberica*, of southeastern Europe and Asia, is a drying oil resembling linseed oil in physical properties. Menhaden and other fish oils are used to adulterate drying oils, but are not considered good drying oils, and give inferior films. Typical examples of nondrying oils are palm oil and castor oil. See Blown oil.

**Duck.** A strong fabric employed for sails, awnings, tents, heavy bags, machine coverings, aprons, and where a very heavy fabric is required. Duck is usually made of cotton but sometimes of linen. It is woven plain, but with two threads together in the warp. It is made in various weights and is designated by the weight in ounces per square yard. It is marketed bleached, unbleached, or dyed in colors. When woven with a colored stripe, it is called Awning duck. Russian duck is a fine variety of Linen duck. Large quantities of cotton duck are used in making laminated resinoid materials and pyroxylin-coated leather substitutes. Belt duck, for impregnated conveyor and transmission belts, is made in loosely woven soft ducks and in hard-woven, fine-yarn hard duck. The weights run from 28 to 36 oz. Hose duck, for rubber hose, is a soft-woven fabric of plied yarns not finer than No. 8, made in weights from 10 to 24 oz. The grade of duck known as Elevator duck for conveyor belts is a hard-woven 36-oz. fabric.

**Duplex metal.** Sheet or plate metal composed of sheets of two different metals rolled together. They were developed commercially only recently, although the process is an old one in the jewelry trade. See Gold shell. Feran, a duplex metal of the Wichender Eisen u. Stahlwerke, was made by passing strips of aluminum and iron at a temperature of 350°C. through rolls and then cold-rolling. The aluminum adheres to the iron, but does not alloy with it to impair its ductility. Alclad, of the Aluminum Company of America, is an aluminum-clad aluminum alloy, with the exposed pure aluminum giving added corrosion resist-

ance, and the aluminum-copper base metal giving strength. The base metal is usually Alcoa 17-S, and the aluminum coating is usually 0.0035 in. in thickness rolled on. It is used for aircraft sheathing. The German Lautal with pure aluminum rolled on is called Allautal. Zinnal, of the Vereinigte Silberhammerwerke Hetzel, is an aluminum sheet coated on both sides with tin rolled on. Cupal is a German copper-clad aluminum sheet. In this case the copper is plated and then rolled in. Chromaloid, of the American Nickeloid Company, consists of a zinc base on which sheet chromium is bonded. The chromium face is highly polished, and the sheets are used for table tops or stamped parts. Nickeloid, of the same company, has a zinc base with polished nickel bonded to the face. Calorized alloys are steel or iron alloys, surface-treated with aluminum by a process patented by the General Electric Company. Calorized steel is used for lead pots and for parts subject to heats up to 1650°F. Insuluminum, of this company, is a steel with a surface impregnation of aluminum to resist hot gases. Nickel-clad steel, used for tanks and corrosion-resistant equipment, consists of sheet steel with nickel on one or both sides bonded by rolling. The nickel is usually from 10 to 20 per cent of the plate thickness. Niclad, of the Flannery Manufacturing Company, has the nickel or nickel alloy deposited on the steel or iron by a continuous welding process. For lead-melting pots the outside covering of nickel gives a heat-resistant surface, and the lead does not come into contact with the nickel where it would have a leaching effect. See also Composite metals.

**Duralumin.** Originally the trade name of the Durener Metallwerke, A. G., and in the United States of the Bausch Machine Tool Company, for a wrought aluminum-copper alloy containing sufficient magnesium to give heat-treating characteristics, and hardened with a slight amount of manganese. The original Duralumin of Alfred Wilm contained 4 per cent of copper, 0.5 magnesium, and 0.5 manganese. In the aircraft and metal-working industries the term Duralumin-type alloy is used to mean any wrought aluminum alloy containing 3 to 4.5 per cent of copper, 0.4 to 1.0 magnesium, 0 to 0.7 manganese, and

the remainder aluminum, with or without very small amounts of iron and silicon. For heat-treating, or age-hardening, Duralumin is quenched from a temperature of about 950°C. and allowed to stand for 4 days. Age-hardening results from chemical combination of the magnesium with the aluminum. Alloys with silicon up to 1.25 per cent are called Super-duralumin. Annealed duralumin has a tensile strength of 28,000 lb. per sq. in., with elongation of 22 per cent and Brinell hardness of 50. After heat-treating and aging the strength is 59,000 lb. per sq. in., elongation 18 per cent, and hardness 95. The metal can be again annealed by raising to a temperature of 650°C. and cooling. The alloy is more ductile than brass. It can be cold-worked, drawn, and forged, and welds easily. It corrodes easily and is also hot short. Alcoa 17-S, of the Aluminum Company of America, contains 3.5 to 4 per cent of copper, 0.2 to 0.5 magnesium, 0.4 to 0.5 manganese, and has a tensile strength of 60,000 lb. per sq. in., with elongation of 20 per cent and Brinell hardness of 95. Bohnalite S17, of the Bohn Aluminum and Brass Corporation, has approximately the same composition. See also Alclad. Other alloys of the duralumin type are Aldrey, Almelec, Aludur, and some grades of Hyblum. Aerolite has less copper, 1.15 per cent, with small amounts of magnesium, zinc, iron, and silicon. Hiduminium 72, of High Duty Alloys, Ltd., is a special-composition duralumin-type metal. See Aluminum alloy.

**Dyestuffs.** Substances employed for giving color to textiles, paper, leather, wood, or other articles. They may be either natural or artificial. The natural dyestuffs are mineral, animal, or vegetable, but the artificial dyes are mainly derived from the coal-tar colors. Tyrian purple, from various Mediterranean snails, was in ancient times the most noted of the animal dyestuffs. Cochineal is another animal dye. Vegetable dyestuffs may be water solutions of woods, barks, leaves, or flowers. These include Brazil wood, barwood, sappan wood, fustic, logwood, madder, henna, saffron, annatto, indigo, and alkanet. Argol, used extensively until replaced by synthetic dyes, is from the Orchilla weed, a moss found in the Canaries and Asia Minor. It was an ancient dyestuff and produced the brilliant reds of the

medieval Florentine cloth. Mineral dyestuffs include ochre, chrome yellow, and Prussian blue. Coal-tar or aniline dyes are made synthetically in all colors and shades. They are more intense, brighter, and faster than natural dyes. There are thousands of these dyes, classified by a color index rather than by their chemical composition. Some adhere to vegetable fibers; some adhere to both vegetable and animal. Some require mordants, or are varied by mordants. Some are permanent; others may fade or be removed by washing. Dyes are "acid" when they operate best in an acid bath, and "basic" when operative in an alkaline bath.

**Dynamite.** A high explosive much used for blasting in mining and in construction work. It was first made by Alfred Nobel in 1867, and consists of nitroglycerin in an absorbent material, usually kieselguhr or wood flour. One part of kieselguhr to three parts of nitroglycerin is molded into sticks, and made up in paper-encased cartridges. It is reddish brown in color. The sticks are usually arranged for exploding with a detonator.

Dynamites are rated on the percentage, by weight, of the nitroglycerin which they contain. In Extra dynamite half of the nitroglycerin is replaced by nitrate of ammonia. It is not so quick and shattering, but is useful in earth excavation. Durox is an ammonium dynamite marketed by E. I. du Pont de Nemours & Company. Agritol is a low-density ammonium dynamite of the same company for blasting stumps and boulders. Gelatin dynamite is made by dissolving a special grade of nitrocotton in nitroglycerin. This type has less fumes, and is thus adapted for underground work. Its plasticity also makes it more adaptable for loading solidly in holes. It is marketed as straight gelatin or as ammonium gelatin. Blasting gelatin is a strong and quick grade, and is waterproof. Gelobel is a gelatin dynamite, and Monobel is an ammonium dynamite marketed by du Pont for mine blasting.

**Eastern red cedar.** The wood of the Juniper tree *Juniperus virginiana*, growing in the Eastern United States from Maine to Florida. It is also called Red cedar, Red juniper, and Savin. The heartwood has a bright to dull-red color and the thin sapwood is

nearly white. The wood is light in weight, soft, weak, and brittle, but is durable. It is used for chests, cabinets, and closet lining because of its reputed value for repelling moths. It was formerly employed on a large scale for lead-pencil wood, and was known as Pencil cedar, but other varieties are now used for this purpose, notably Incense cedar, *Libocedrus decurrens*, of California and Oregon. African pencil cedar is from the tree *Juniperus procera*, of East Africa. It is harder and heavier, and less fragrant than incense cedar.

**East India walnut.** The wood of the tree *Albizzia lebbek*, of tropical Asia and Africa, having a wide variety of uses for furniture, flooring, paneling, and decorative work. It is a hard, dense, close-grained wood having a weight of about 50 lb. per cu. ft. The color is dark brown with gray streaks. It takes a fine glossy polish. The logs come as large as 30 in. square, and 20 ft. long. The shipments of East India walnut are likely to be mixed with *Albizzia procera*, the White siris wood of India. This wood has a brown walnut color, is lustrous and streaky, and resembles true walnut more than does the East India walnut.

**Ebonite.** A name formerly used for black vulcanized rubber made generally from the cheaper grades of rubber, and employed for electrical parts, handles, and novelties. It contains 30 per cent or more of sulphur and is hard and brittle. Ebonite has been largely replaced by standard hard rubber, or by synthetic molded resins. See Hard rubber.

**Ebony.** A hard, black wood valued for parts subject to great wear, and for inlaying. It is the wood of various species of trees of the ebony family, *Ebenaceae*, although the name is also applied to some woods of the genus *Dalbergia*, family *Leguminosae*. Black ebony, from the tree *Diospyros dendo*, of West Africa, and ebony, from the tree *D. melanoxylos*, of India, are the true ebonies. Black ebony has a black heartwood with brownish-white sapwood. It is next to lignum vitae in hardness, has a fine, open grain, and weighs 78 lb. per cu. ft. It is used for inlaying, piano keys, and turnery. Ebony, of India, is also extremely hard, with a fine and even grain. The heartwood is black with

brownish streaks. Marble ebony is from a species found in Madagascar. Ebony wood is shipped in short billets, and is graded according to the color and the source, as Niger, Macassar, Cameroon. Green ebony is a name sometimes given to the cocoswood of the West Indies. The ebony from Japan, also called Kaki, is from the tree *D. kaki*. It has a black color streaked with gray, yellow, and brown. The grain is close and even, and the wood is very hard, but the weight is less than that of African ebony. See also Marblewood. Artificial ebony, formerly composed of asphaltic compounds, is now usually synthetic resins molded to shape.

**Egyptian blue.** A blue coloring material composed of a double silicate of calcium and copper, $CaO \cdot CuO \cdot 4SiO_2$. It resists the action of most chemical reagents. It was originally made by fusing sand, soda, and copper. It was employed by the Romans, and paintings 1,900 years old have retained the color. It is now made by fusing finely powdered quartz, chalk, copper oxide, and sodium carbonate, and washing with hydrochloric acid.

**Electrolytic iron.** A chemically pure iron produced by the deposition of iron by an electric current in a manner similar to electroplating. Bars of cast iron are used as anodes, and dissolved in an electrolyte of ferrous chloride. The current dissolves almost pure iron on the cathodes, which are hollow steel cylinders. The deposited iron tube is removed by hydraulic pressure or by splitting, and then annealed and rolled into plates. Electrolytic iron is produced 99.965 per cent pure iron. It is employed for magnetic cores, for special purposes where ductility and purity are required, and in the manufacture of alloys.

**Elemi.** A soft, sticky, opaque resin with a pleasant odor, obtained from the pili tree, *Canarium luzonicum*, of the Philippine Islands, and employed for giving body to lacquers. It is substituted for dammar, as it is generally cheaper. Other substitute elemi resins are obtained from various trees of the family *Burseraceae* of tropical America and Africa. The pili trees are hacked or stripped, and the resin collects on the bark. Each tree yields about 5 lb. per year. West Indian elemi comes from the

tree *Dacryodes hexandra*, of the West Indies. Elemi oil is a colorless liquid having a specific gravity of 0.87 to 0.91, obtained by distilling the gum.

**Elkskin.** Also known as Elk leather. The commercial name for a soft, pliable, and durable leather made from kips or overgrown calf by a special tanning process. It is used chiefly for children's shoe uppers and for pocketbooks. A heavier elkskin for sport shoes and boots is made from cow hides by special treatment and impregnation with oils and greases. Elkskin has the property of drying out to its original softness after wetting. Smoked elk is elk leather dyed cream colored to imitate the original leather of elks, which was exposed to the smoke of wood in the tanning.

**Elm.** The wood of numerous species of the elm tree, of the United States, Canada, and northern Europe. The common elm of Europe, *Ulmus campestris*, is a rather hard wood with a coarse, open cross-grain, having dark-brown heartwood and white sapwood, but the wood is not employed industrially in the United States. American elm, *Ulmus americana*, has a finer grain, and a weight of about 40 lb. per cu. ft. It is whitish brown in color, hard and tough. Rock elm, *Ulmus racemosa*, is also native to the United States and Canada. It has a very fine, close grain and is slightly heavier. Elm wood is tough and durable, and is used in making various implements and ax handles.

**Emery.** A fine-grained, impure variety of the mineral corundum, mixed with other minerals, chiefly magnetite. It occurs as a dark-brown granular massive substance, with a specific gravity of 3.7 to 4.3 and a hardness of about 8. It usually contains only 55 to 75 per cent of $Al_2O_3$. It is used as an abrasive either ground into powder or in blocks and wheels. The grains are graded in sizes from No. 180 mesh, the finest, to No. 8, the coarsest. Emery paper and cloth are usually graded from 24 to 120 mesh, and the grains are glued to one side of 9 by 11 sheets. Flour of emery is the finest powder, usually dust from the crushing. Emery takes its name from Cape Emeri, on the Island of Naxos. Small amounts are produced in New York state. Emery is

now largely replaced by artificial aluminum oxide, which can be graded more uniformly. Emery cake is made up of aluminum oxide for buffing and iron oxide for polishing. It is furnished in various grades of fineness, with grains of 120 to 200 mesh or flour sizes F, FF, and FFF. See Aluminum oxide.

**Enamel.** A protective coating or paint which upon hardening has an enameled, or glossy face. Ordinary pottery enamels are chiefly composed of quartz, feldspar, clay, soda, and borax, with saltpeter or borax used as fluxes. The quartz supplies the silica, and such enamels are fusible glasses. To make them opaque Opacifiers are used. These may be tin oxide for white enamel, cobalt oxide for blue, or platinum oxide for gray. In acid-resisting enamels alkali earths may be used instead of borates. Tin oxide is the most used opacifier, and up to 3 per cent also increases the fusibility of the enamel. An Opacifier must have fire resistance so as not to vitrify or decrease the luster. Enamels applied to metals are fired at a red heat, and each succeeding coat must have a lower melting point than the one before it. They must also have about the same coefficient of expansion as the metal. White glass enamel is easily fusible and is much used on brass clock dials and scales. Cloisonné enamel is an ancient decorative enamel produced by soldering thin strips of gold on the gold base metal to form cells into which the colored enamel is pressed and fused in place. It is still produced by the old hand methods, but is imitated in synthetic plastics for such articles as clocks and radios. Enameloid-cloisonné is a trade name for such use by the Gemloid Corporation.

The word enamel in the paint industry refers to paints of ground oxide or sulphate pigments mixed with varnish to give a glossy face. They do not have the heavy body of a paint and require undercoats. Baking enamels, however, are of similar compositions to japan, and give durable, lustrous coats, or they may be synthetic resin lacquers with plasticizers. Quick-drying enamels are cellulose lacquers with pigments. Fibrous enamel, used for painting roofs, is an asphalt solution in which asbestos fibers have been incorporated. When of heavy consistency and used for caulking metal roofs, this material is called Roof putty.

C-enamel is a lacquer composed of gums and oil treated with zinc oxide. It was patented by the National Canners' Association for use on tin plate for making cans for packing nonacid foods.

**Engine sand.** Also known as Traction sand. Sand employed to prevent the driving wheels of locomotives or other vehicles from slipping on wet rails. Engine sand is usually washed to free it of soft bond and fine particles. The Pennsylvania Railroad requires engine sand to contain at least 95 per cent of silica, all grains to pass through a No. 20 sieve and be retained on a No. 80.

**Erbium.** An exceedingly rare metal, symbol Er, which occurs in the rare mineral gadolinite found in Greenland and Sweden. Erbium is supposed to resemble aluminum in its physical properties, but due to its rarity has as yet no commercial use.

**Etching materials.** Acids, or other substances, used for etching on metals, glass, or other material. The usual method is to coat the surface with wax, or other substance not acted upon by the acid, cut the design through with a sharp instrument, and then allow the acid to corrode or dissolve the exposed parts. Beeswax, rosin, asphalt, gum varnishes, or mixtures may be used for the protective surface. For etching steel, a 20 per cent solution of nitric acid in water is used. For very hard steels acetic acid may be mixed with the nitric acid. For etching stainless steels a solution of ferric chloride and hydrochloric acid in water in the proportion 5:1:6 may be used. For high-speed steels, brass, or nickel, a mixture of nitric acid with hydrochloric is used in solution. Copper may be etched with a solution of chromic acid. Brass and nickel silver are etched with an acid solution of ferric chloride to which is added potassium chlorate. For red brasses deep etching is done with concentrated nitric acid mixed with 10 per cent of hydrochloric acid, the latter being added to keep the tin oxide in solution and thus retain a surface exposed to the action of the acid. For etching aluminum a 9 per cent solution of copper chloride in 1 per cent acetic acid, or a 20 per cent solution of ferric chloride may be used, followed by a final wash with strong nitric acid. Sodium hydroxide, ammonium hydroxide, or any alkaline solutions are also used for etching aluminum. Zinc

is preferably etched with 1 per cent nitric acid, but takes a long time and frequent renewal of acid. Stronger acid is not used because of the heat generated, which destroys the wax coating. Glass is etched with White acid, or with hydrofluoric acid. White acid is a mixture of hydrofluoric acid and Ammonium bifluoride, the latter being a white crystalline material of the composition $(NH_4)FHF$.

**Ether.** The common name for Ethyl ether, a highly volatile, colorless liquid of the composition $(C_2H_5)_2O$, used as a solvent for fats and greases, and in pyroxylin manufacture. Ether boils at 34.5°C. and burns readily. The specific gravity is 0.720. In the manufacture of guncotton and pyroxylin plastics it is mixed with alcohol. Its vapors are heavier than air and are explosive. Other forms of ether are also used. Butyl ether, of the composition $(C_4H_9)_2O$, has a much higher boiling point, about 140°C. and is more stable. It is a solvent for gums and resins. See Solvents.

**Ethyl acetate.** A liquid of the chemical composition $CH_3COOC_2H_5$, made for ethyl alcohol and acetic acid. It is an important solvent, especially for nitrocellulose compounds, varnishes, and lacquers. The specific gravity is 0.924, and boiling point 77°C. It has a pleasant, aromatic odor.

**Ethyl alcohol.** The common beverage alcohol, which when denatured for nonbeverage purposes is called Industrial alcohol. See Denaturants. It is a colorless liquid with a pleasant odor but burning taste. Its chemical formula is $CH_3CH_2OH$, its specific gravity 0.79. It mixes with water in all proportions and takes up moisture from the air. It burns with a bluish flame and high temperature, yielding carbonic acid and water. The ignition temperature is 965°F. in air at atmospheric pressure. It is one of the best solvents, and dissolves many organic substances such as resins and essential oils, making solutions called essences. It is classed as a poison when pure, but is employed as a beverage in many forms. In small quantities it is a narcotic. Ethyl alcohol is made synthetically under the name of Ethanol, but is produced cheaply by the fermentation of sugars, grains, and starch. See Alcohol. It is used as a solvent in varnishes, enamels, explosives,

liquid soaps, extracts, perfumes, and drugs, and as a raw product in making other compounds. It is also used as a preserving agent and as a fuel. Monopolin is a German motor fuel for aviation engines, consisting of a mixture of absolute alcohol and benzine. Monopolin R contains wood alcohol. Due to its low freezing point, −112°C., alcohol is used in thermometers, and as an antifreeze mixture. See also Motor fuel.

Alcohol is sold by the "proof gallon," a 100 proof containing 50 per cent alcohol by volume and having a specific gravity of 0.7939 at 60°F. The term Alcohol, alone, refers to 188 to 192 proof. High-purity, Grain alcohol, or Pure ethyl alcohol, are terms for 190 proof. Absolute alcohol, or Anhydrous alcohol, is 200 proof, free of water. Methylated spirits is a term first used in England to designate the excise-free mixture of 90 per cent ethyl alcohol and 10 per cent wood alcohol for industrial use. Denatured ethyl alcohol, made unsuitable for beverage purposes, is marketed under trade names, such as Synasol. Solox is the name of a solvent alcohol of the U.S. Industrial Chemicals, Inc., consisting of 100 parts of 190-proof alcohol, 5 parts of ethyl acetate, and 1 part of gasoline, and used for lacquers, fuel, and as a solvent for shellac. A substitute for ethyl alcohol for solvent purposes is Isopropyl alcohol, or Isopropanol, a colorless liquid of the composition $(CH_3)_2CHOH$, and boiling point 82°C. It is also used as a stabilizer in soluble oils and in drying baths for electroplating.

**Ethyl chloride.** A gas of the composition $C_2H_5Cl$, sometimes employed as a refrigerant in household refrigerators. It is sold compressed into cylinders as a colorless liquid. It is also known as Monochlorethane, Kelene, and Chelene. Its disadvantages as a refrigerant are that it is highly inflammable, and that leaks are difficult to locate. The specific gravity of 0.921, freezing point −140.8, and boiling point 12.5°C. The condensing pressure in refrigerators is 12.4 lb. gage at 6°F., and the pressure of vaporization is 10.1 lb. gage at 5°F.

**Ethylene glycol.** Also known as Glycol, and Ethylene alcohol. It is a colorless, sirupy liquid with a sweetish taste, and of the composition, $CH_2OHCH_2OH$. It has a very low freezing

point and is employed as an "antifreeze" in automobile radiators as it is soluble in water. It has the advantage over alcohol for this purpose that it does not boil away easily. Its boiling point is 197°C., and solidifying point −23°C. The specific gravity is 1.125. A 25 per cent solution has a freezing point at −5°F. without appreciably lowering the boiling point of the water. Used in airplane engines it permits operation of the engine at a temperature of 300°F. instead of 180°F. with water, thus giving greater fuel efficiency. It is also employed as a substitute for glycerin and as a solvent for nitrocotton in the manufacture of dynamite. Prestone is the trade name of the National Carbon Company for ethylene glycol employed for automobile radiators. Diethylene glycol, used as a solvent, as an antifreeze, and for softening cotton and wool fibers in the textile industry, is a water-white liquid with a boiling point at 244°C. A 50 per cent solution of diethylene glycol freezes at −28°C. Cellosolve is the trade name of the Carbide and Carbon Chemicals Corporation for the monoethyl ether of ethylene glycol. It is a water-white liquid which is a powerful solvent used in varnish removers, cleaning solutions, and in paints, lacquers, and in soluble oils. Carbitol, of the Carbide and Carbon Chemicals Corporation, is an ether of diethylene glycol. It is a water-white liquid, boiling at 201.9 and freezing at −76°C. It is used as a solvent for oils, dyes, resins and gums. The chemical formula is $CH_3CH_2OCH_2CH_2OCH_2$-$CH_2OH$. Methyl carbitol, with one less $CH_2$ group, is also a high-boiling-point solvent for gums and resins. Carbitol acetate is also a high-boiling-point solvent for cellulose acetate.

**Ethyl silicate.** A colorless liquid of the composition $(C_2H_5)_4SiO_4$, used for making heat-resisting paints, for acid-proof cement, for molded objects, and for preserving stone. Water hydrolyzes the liquid to alcohol and Silicic acid, $H_4SiO_4$, which changes to an adhesive form of silica. For molding, the ester is mixed with silica powder. Machinery bearings have been made by mixing with about 25 per cent of wood flour. The wood absorbs and retains the lubricating oil, and the hardened silica forms a hard wearing surface. Ethyl silicate solutions are also used for surface hardening of sand molds and graphite molds for

special casting. Silicic acid ester paints are used to harden and preserve stone, cement, or plaster, and also for coating firebrick. They are resistant to heat and chemical fumes. Lacquers containing ethyl silicate have high adhesion to glass. See Water glass.

**Europium.** An extremely rare elementary metal found in monazite sand. The chemical symbol is Eu. It is not yet a commercial article. Its oxide, $Eu_2O_3$, is obtained in the form of a pink powder.

**Excelsior.** A general trade name for Wood wool, or continuous, curly, fine wood shavings, employed chiefly as a packing material to prevent breakage of fragile articles in shipping. The raw material used in its manufacture is mainly aspen and basswood in logs or bolts, or it may be made as a by-product of other wood manufactures.

**Expanded metal.** Sheet metal that has been slit and expanded to form a mesh, which is used for reinforced concrete work or plaster wall construction. It is made either with a plain diamond-shaped mesh, or with rectangular meshes. One type is made by slitting the sheet and stretching the slits into the diamond shape. The other variety is made by pushing out and expanding the metal in the meshes so that the flat surface of the cut strand is nearly at right angles to the surface of the sheet. Ordinary diamond-shaped expanded metal is used for concrete floors. Expanded metal is made from low-carbon steel, iron, or special metals. It comes ordinarily in sheets varying from 8 to 12 ft. in length, and 3 to 6 ft. in width, in several thicknesses. It is also made up into metal lath, usually 96 in. long, and from 14 to 18 in. wide.

**Expansive metal.** An alloy metal which expands on cooling, and is used for filling small holes or defects in metal parts or castings. A typical alloy is composed of 9 parts of lead, 2 of antimony, and 1 of bismuth. The expansion on cooling is due to the effect of the antimony and bismuth, both metals having this property. The expansive property of certain metals is an important characteristic in the production of accurate castings, such as type. See Type metal. The property is also made use of in metals

for making impressions of molds, for sealing, and for holding die parts in place in tools. Lewis metal, one of the original alloys for this purpose, had 1 part of tin and 1 of bismuth, and melted at 138°C. Matrix alloy, and Cerromatrix, produced by the Cerro de Pasco Copper Corporation, is a low-melting-point expansive metal used especially for tool holding. It contains 48 per cent of bismuth, 28.5 lead, 14.5 tin, and 9 antimony. The melting point is 248°F., tensile strength 13,000 lb. per sq. in., and Brinell hardness 19. Cerrobase, of this company, is alloyed to make it nonshrinking, for making duplicates of master patterns, for proof-casting forging dies, and for molds for plastics. It is harder than lead, and melts at 255°F.

**Explosive.** A substance or mixture of substances which upon application of a blow to a portion of its mass, or by a rise in temperature, is converted in a small space of time into other substances more stable, and occupying more space. Commercial explosives are solids or liquids that can be instantaneously converted by friction, heat, shock, or spark, into a large volume of gas. The chemical changes thus produced develop a sudden rise in pressure, which is utilized for blasting or propelling purposes. Gunpowder is the oldest form of commercial or military explosive, but this has been replaced for military purposes by the modern smokeless powders. Blasting powders are required to be slow acting, and have a heaving and rending effect. Military explosives used as propellants must not give instantaneous detonation, which would burst the gun, but are arranged to burn slowly at first and the explosion does not reach a maximum until the projectile reaches the muzzle. Most Smokeless powders have guncotton as a base. Explosives such as nitroglycerin can be exploded by themselves, but others require oxygen carriers or carbon carriers mixed with them. The rapid-acting explosives derived from aniline or benzene are generally used for bombs and torpedoes. Other requirements of explosives are that they must not react with steel or brass, must be stable at ordinary temperatures, and should not decompose easily in storage or on exposure to the air. High explosive is a name given to detonating powders fired by shock from an intermediate agent called a Detonator,

and the transformation to gas is exceedingly rapid and the volume of gas great, giving a high shattering effect. Permissible explosives are explosives which have been passed by the Bureau of Mines as safe for blasting in gaseous or dusty mines. Most of the permissibles are of ammonium nitrate or gelatin base. Lox, used in mines and quarries, is an explosive consisting of a paper cartridge filled with carbon black or wood pulp, soaked in liquid air. It cannot be tamped, as it is more sensitive than dynamite. It is fired by electric detonators. Cardox, an explosive used in coal mining, consists of liquid carbon dioxide in a steel cylinder with aluminum powder. The powder is fired by an electric spark, heating and expanding the carbon dioxide. See Gunpowder, Dynamite, Tetryl, Hexa-nitro-diphenylamine, Trinitrotoluene, Tetra-nitroaniline, Picric acid, Azoimide, Sprengel explosives.

**Explosive D.** The common name for Ammonium picrate, $NH_4C_6H_2(NO_2)_3O$, also known as Dunnite. It was patented in 1888, and is important chiefly as a military explosive due to its insensitiveness to shock or friction, making it suitable as a bursting charge in armor-piercing shells. It is soluble in alcohol and in water, and crystallizes in orange-yellow needles. It explodes when heated to 300°C. It is made by the neutralization of picric acid with ammonium carbonate, or ammonium hydroxide, with subsequent crystallization.

**Fat liquors.** Oil and grease emulsions used in tanneries to make the tanned leather more flexible, to lubricate the fibers, and to improve the finish. There are two general types of fat liquor emulsions, acid and alkaline. The acid group includes sulphonated oils and some soluble oil combinations. Alkaline types are emulsions of oils with soaps or alkalies. Leather may also be treated first with an alkaline liquor and then with an acid; or borax or soda ash may be added to sulphonated oils to produce alkaline liquors. For suède and white leathers, egg yolk emulsions may be used. Oils used in emulsions may be sperm, cod, or castor oil. The neutral liquors have a neat's-foot oil base. The oils may be marketed under trade names. The soaps are usually special for the tannery trade. The Tanners' greases, used

for sponging or milling on the leather, are also usually trade-named mixtures of waxes, sulphonated oils, and soaps.

**Feldspar.** A name given to a group of abundant minerals used for vitreous enamels for metal parts, and also used for making pottery, tile, and glass. All of the chemical components of feldspar are glass-making materials, and in making glass about 150 lb. are used to each 1,000 lb. of sand. There are a large number of varieties. Orthoclase is the potash feldspar, or potassium-aluminum silicate, $K_2O{\cdot}Al_2O_36SiO_2$. Feldspar in its natural occurrence varies widely in composition even in the same mine, and thus must be controlled chemically to obtain uniform results in enamels. It is ground to a uniform size, from 20 to 80 mesh, and shipped in bags. The firing point varies, as also the expansion factor. Tennessee and North Carolina feldspar has about 70 per cent of $SiO_3$ and 17 per cent of $Al_2O_3$, with 9 to 11 per cent of $K_2O$, and 2 to 3 per cent of $Na_2O$. New England feldspar is lower in $SiO_2$ and higher in $K_2O$. Potash spar from New York and New Jersey has about 12 per cent of $K_2O$, and is suited for glass and pottery. Soda spar, with about 7 per cent of $Na_2O$, is preferred for ceramic enamels. Cornwall stone, imported from England, is a kaolinized feldspar with about 2 per cent of CaO. A similar stone comes from North Carolina and is known as Carolina stone. Aplite is a ceramic fluxing stone found in Virginia and used chiefly to supplement feldspar to provide more alumina. It is a white massive material of Albite, feldspar, and other minerals. It contains about 60 per cent of silica and 24 of alumina, with 6 per cent of CaO, 6 of $Na_2O$, and 3 of $K_2O$. Another substitute for feldspar is Alaskite, a feldspar and quartz mixture from North Carolina. Ground feldspar used for enamels is sometimes called Glass spar. Crude unground feldspar is also marketed.

**Felt.** A fabric of wool, fur, or hair made by matting the fibers together under pressure when thoroughly soaked or steam heated. The matting may also be accomplished by blowing the wet fibers under a powerful air blast and then pressing. The animal fibers mat together due to minute scales on their surface. Cotton and other vegetable fibers do not have the property of

felting, but felt is sometimes made from a mixture of cotton with wool, hair, or fur. Felt is the most ancient of all fabrics. It has now a wide variety of uses and is made in many plain colors. Woolen felts are used for padding and lining for instruments and machinery parts and many other industrial purposes. Hair felt is largely used as an insulating material. See Hair felt, and Baize. The best felts are employed for hats, and are made of nutria or beaver fur, although vast quantities of rabbit furs or mixed furs and wool are used for hat felts. Felts vary widely due to differences in the quality of the wool or other material, and methods of manufacture. Felt is marketed in many thicknesses. Feltex is an asphalt-saturated felt produced by the Philip Carey Company for roofing. Mica-kote is the trade name of the same company for a roofing felt made by coating a heavy felt with asphalt and finishing with mica flakes. Slaters felt is a tarred sheathing felt used in building construction. Fire felt is the trade name of Johns-Manville for a material made of asbestos, fiber felted and formed into sheets, blocks, or shapes, for boiler and furnace construction. Slatekote, of the same company, is a heavy asphalt-saturated rag felt covered with colored crushed slate, used for roofing.

**Ferric oxide.** A name given to Red iron oxide, $Fe_2O_3$, found in abundance as the ore hematite, or made by calcining the sulphate. It has a dark-red color and comes in powder or lumps. The specific gravity is about 5.20, and the melting point is about 1550°C. Red ferric oxide is used as a paint pigment under such names as Indian red, or Persian red, in cosmetic rouge, and in polishing compounds under the name of rouge. The brown ferric oxide is made by the action of ferrous sulphate and sodium carbonate. It is not a pure oxide. It is used as a paint pigment. Black ferric oxide is a reddish-black amorphous powder, and is made by burning iron in an excess of oxygen. It has the composition $FeO \cdot Fe_2O_3$. Black iron oxide is used as a paint pigment, for polishing compounds, and in heat-treating work for decarbonizing steel. Magnetic black is a trade name for finely ground magnetic oxide used as a pigment. Venetian red is a name applied to red iron oxide pigments mixed with various fillers. Ferric oxide

pigments make low-priced paints, which are used for painting structural work. The oxides come chiefly from Alabama, Tennessee, and New York. See Hammer scale, Rouge.

**Ferroaluminum.** An alloy of iron and aluminum used in steel making as a deoxidizer, or in the foundry for adding aluminum to steel or adding iron to aluminum alloys. Two commercial grades of ferroaluminum marketed by the Niagara Falls Smelting and Refining Corporation contain 20 and 50 per cent of iron, respectively, and the remainder aluminum. The first grade melts at 1900°F., and the second at 2100°F. With 50 per cent of aluminum the alloy is extremely brittle and breaks into pieces.

**Ferroboron.** An iron alloy containing about 18 to 25 per cent of boron, and used in the making of boron steels and for deoxidizing alloys. It is prepared by reducing boric acid in a fused bath of iron. Electromet ferroboron, of the Electro Metallurgical Company, has 18 to 25 per cent boron and a maximum of 3 per cent of aluminum and 3 of silicon.

**Ferrochromium.** A high-chromium iron alloy used in the foundry for mixing to form chromium alloy steels. It is made from chromite ore by smelting with lime, silica, or fluorspar in an electric furnace. Ferrochromium contains from 60 to 70 per cent of chromium, from 0.75 to 7 per cent of carbon, and small amounts of manganese, silicon, phosphorus, and sulphur. High-carbon ferrochrome of the Electro Metallurgical Company contains 4.5, 5, 6, and 7 per cent of carbon, and 66 to 70 per cent of chromium. It is used for making tool steels, ball-bearing steel, and automobile steels. It melts at about 1250°C. It is marketed as "crushed alloy" in sizes up to 2 in., and as "lump alloy" in lumps up to about 75 lb. Low-carbon ferrochrome contains 0.06, 0.10, 0.15, 0.20, 0.50, 1.00 and 2 per cent of carbon, and from 67 to 72 per cent of chromium. It is used for making acid-resisting and stainless steels, and various chromium steels. The various grades of ferrochromium are also marketed with about 0.75 per cent of nitrogen for use in making high-chromium cast steels which would normally have a coarse crystalline structure. The nitrogen refines the grain and increases the strength.

**Ferromanganese.** A high-manganese iron alloy used for making manganese alloy steels and manganese bronze, and for deoxidizing steels. Manganese cleanses the steel by combining with the sulphur and also by forming oxides and producing a fusible slag. Ferromanganese is made either in the blast furnace or in the electric furnace. Standard ferromanganese has 78 to 80 per cent of manganese. British ferromanganese contains about 7 per cent of carbon, but the American content is usually 5 to 6.5 per cent. Low-carbon ferromanganese is also marketed containing 0.10 to 1 per cent of carbon, and Low-phosphorus ferromanganese contains less than 0.10 per cent of phosphorus. Ferromanganese has the advantage over spiegeleisen that smaller amounts are required to obtain the required percentage in the steel, and it can be added without premelting. It is usually marketed in lumps, and added in the furnace.

**Ferromolybdenum.** An alloy of molybdenum with iron, containing up to 85 per cent of molybdenum. It is employed in the making of alloy steels for the purpose of adding molybdenum to the steel, but is being partly replaced by the use of calcium molybdate. Ferromolybdenum is manufactured in the electric furnace from the mineral molybdenite by reduction with carbon and silicon using lime to slag the sulphur, and adding iron turnings. Ferromolybdenum may contain a high percentage, up to 4 per cent, of carbon, but the standard commercial grade contains 50 to 60 per cent of molybdenum with not over 2.5 per cent of carbon. Low-carbon ferromolybdenum, used for low-carbon steels, has 55 to 65 per cent of molybdenum with not over 0.25 per cent of carbon.

**Ferrophosphorus.** An iron containing a high percentage of phosphorus, used for adding phosphorus to steel, chiefly in the making of tin plate. The phosphorus in the steel is intended to prevent sticking together of the plates in annealing. Small amounts of phosphorus are also employed in open-hearth screw stock to make it free cutting, and in some cast irons. Ferrophosphorus is made by melting phosphate rock together with the ore in making the pig iron. The phosphorus content is about 18 per cent and is chemically combined with the iron. Another

grade containing 23 to 25 per cent of phosphorus is made in the electric furnace, and used to add phosphorus to bronzes.

**Ferroselenium.** A master alloy of selenium and iron, employed for adding selenium to rustless irons and steels to give free-machining qualities. A typical analysis of ferroselenium from the American Smelting and Refining Company is: Selenium 52.1 per cent, iron 41.4 per cent, carbon 0.90 per cent with small quantities of silicon, phosphorus, and sulphur. A Selenium steel of the Lebanon Foundry, Circle L12M, contains 13 per cent chromium, 0.25 selenium, and 0.10 carbon. It is a cast stainless steel of good machinability. The tensile strength is 85,000 lb. per sq. in., elongation 20 per cent, and Brinell hardness 170.

**Ferrosilicon.** A high-silicon iron used extensively for making silicon steels, and for adding silicon to transformer cast irons. It is a product of the electric furnace, and is made from quartz or silica, iron turnings, and carbon. It is produced in several grades with the silicon content varying from 15 to 90 per cent. Thirty per cent ferrosilicon contains 68 per cent of iron, and very small quantities of carbon, manganese, and such impurities as sulphur and phosphorus. Silicon forms a chemical combination with iron, and alloys with more than 30 per cent of silicon are likely to disintegrate. When the silicon content increases above 4 per cent, carbon is excluded in flakes of graphite. One of the large producers manufactures two grades, 15 per cent and 45 per cent, while another standardizes on 15, 50, 75, 85 and 90 per cent. It is marketed in lump or crushed forms. Silicon metal is a name given to the alloys of highest silicon content. Silvery iron is a name used in steel mills for pig iron of high silicon content because of its silvery fracture. Ferrosilicon is also used for the insoluble anodes in the electrolytic reduction of copper.

**Ferrosilicon aluminum.** An alloy containing about 45 per cent of silicon, 12 to 15 per cent of aluminum, and the remainder iron. It is used as a deoxidizer in steel making in the electric furnace. It is usually put in the ladle, and is more effective than aluminum for deoxidizing steels. It is also employed for adding

silicon to aluminum casting alloys. Silvaz is the trade name of the Electro-Metallurgical Company for a ferro alloy containing silicon, aluminum, vanadium, and zirconium. This alloy cleanses the steel and also controls grain size. The aluminum serves as a deoxidizer and fluxes the slag inclusions.

**Ferrotitanium.** An alloy of titanium with iron used as a purifying agent for steel due to the great affinity of titanium for oxygen and nitrogen at temperatures above 800°C. The Ferro-carbon-titanium is made from ilmenite in the electric furnace, and the carbon-free alloy is made by reduction with aluminum. The value of the alloy is as a cleanser, and little or no titanium remains in the steel. Alloys containing more than 18 per cent of titanium are difficult to use owing to their high melting point. Federal Specification grades are Grade A with 25 to 30 per cent titanium, 3 silicon, 6 aluminum, and 0.25 carbon, and Grade B with 15 to 18 per cent titanium, 3 silicon, 1.5 aluminum, and 7.5 carbon. Ferrotitanium comes in lumps, crushed, or screened.

**Ferrotungsten.** An alloy of iron and tungsten containing 65 to 75 per cent of tungsten, or sometimes more, and not over 1 per cent of silicon. It is used for mixing with steel to form tungsten and other alloy steels. Ferrotungsten is one of the oldest iron alloys, having been made first by Berthier in 1834. It is now made in the electric furnace by reduction of the oxide $WO_3$, and iron, or by reducing tungsten ores with carbon or silicon. The melting point is usually 3200 to 3450°F., the minimum melting point of the iron-tungsten system being 2770°F. Because of its high melting point it is not tapped, but the solid mass is taken from the cold furnace and broken into lumps. It is marketed in lumps.

**Ferrous sulphate.** Also called Iron sulphate, Copperas, or Green vitriol, is a green crystalline substance of the composition $FeSO_4 \cdot 7H_2O$. It is produced by the action of dilute acid on iron, and is a by-product of the galvanizing and tinning industries, being recovered from the pickling baths. The specific gravity is 1.898, melting point 64°C. It is soluble in water but insoluble in alcohol. On exposure to the air it becomes yellowish, due to the

formation of a basic iron sulphate. Copperas is the most important salt in the ink industry, used to give permanent color to the inks. It is also employed in water purification, as a disinfectant, in polishing rouge, and as a blue pigment, although the pigment known as Prussian blue and Chinese blue is the blue amorphous powder, Ferric ferrocyanide, $Fe_4(FeCN_6)_3$.

**Ferrovanadium.** An alloy of the metal vanadium with iron, employed in the steel industry for adding vanadium to the steel, and as a powerful deoxidizer. It is made by reduction with carbon in the electric furnace of ferrous vanadate, calcium vanadate, or the oxides. There are various grades of the alloy, with vanadium contents up to 45 per cent, and carbon up to 6 per cent. Some grades contain silicon up to 15 per cent. For use in steel, the carbon content should be low. Grade A normally contains 30 to 40 per cent of vanadium with 3 to 6 per cent of carbon and 8 to 15 silicon, but it is also marketed with carbon not over 0.20 per cent and silicon not over 1.5 per cent.

**Fiberboard.** Heavy sheet material of fibers matted and pressed or rolled to form a strong board, used for making trunks and boxes and also for partitions in building construction. The fibers may be of wood or cellulose, jute, flax, straw, or fibers specially compounded and vulcanized. Board made of asbestos fibers is not usually classed as fiberboard. A pressed flexible fiberboard used as an insulating material for walls is produced of matted flax and rye straw fibers by the Union Fiber Company, Inc., under the name of Fibrofelt. The thickness is from 5⁄16 to 1 in. A wood-fiber board of the Masonite Corporation, under the name of Masonite, is produced from by-product wood chips reduced to the cellulose fibers by high-pressure steam. The long fibers and the lignin adhesive of the wood are retained, and no chemicals are used in pressing the pulp into boards. Masonite quarter board, for paneling, is made in boards 1⁄4 in. thick. Presdwood is a trade name for a grainless grade made by compressing under hydraulic pressure; it is dense and strong. Kimflex board, of the Kimberly-Clark Mills, is a light-weight, pliable, and flexible fiberboard used for shoe counters. It is made from balsawood pulp to which rubber latex is added. Electrite, of the

West Virginia Paper and Pulp Company, is a wood fiberboard of high strength and high dielectric strength used for electrical insulation. Temlok, of the Armstrong Cork Products Company, used in building construction, is a fiberboard made from fibers of southern pine impregnated with resin and compressed into boards and tiles. Temwood, of the same company, is a light-weight, hard, and semihard board made of wood fibers hydraulically pressed into grainless boards. Temboard is a decorative board of wood fibers used for interior work. Disfico board, produced by the Diamond State Fibre Company for making trunks and boxes, is made of pressed jute and hemp fibers. It comes in sheets in plain colors. See also Vulcanized fiber. Thermax, of the Northwest Magnesite Company, is an insulating board made of long shredded wood fibers, with a fire-resistant cement, rolled into sheets, and marketed in standard sizes.

**Filter sand.** A natural sand employed for filtration, especially of water. The commercial production of filter sand in the United States is about 100,000 tons annually. The largest producers of specially prepared filter sand are New Jersey, Illinois, and Minnesota. Filter sand is prepared from ocean beaches, lake deposits, and sand banks. It must be of fairly uniform size, free from clay and organic matter, and chemically pure. It is always washed and dried before shipment. Filter-sand grain sizes are specified in millimeters. The most commonly specified have effective sizes from 0.35 to 0.65 mm. Very fine sand clogs the filter and is objectionable. The maximum content of combined carbonates is usually specified as not more than 2 per cent.

Greensand, produced from extensive beds in New Jersey, is used as a water softener. It is a type of marl classed as Zeolite, and consists essentially of Glauconite, containing about 75 per cent of silica and iron oxide, with potash and alumina. The action of the softener is to abstract the calcium and magnesium from the water, replacing with sodium salts. Greensand is regenerated for further use by passing common salt brine through it. See also Fuller's earth.

**Finishing steel.** An indefinite term for tool steels that will retain a fine cutting edge for finishing work at high speeds. They

are usually semi-high-speed steels. They are deep hardening and have low resistance to shock, but for light cuts will hold a better cutting edge than carbon steels or high-speed steels. These steels usually have from 1.5 to 3.5 per cent of tungsten, from 1.15 to 1.40 carbon, and sometimes small amounts of chromium and vanadium. They are used for finish cutting tools, taps, broaches, and dies. Those with tungsten, but no chromium and vanadium, are called Keen-edge steel. They have an intensely hard smooth surface and a coarse-grained core. Those with chromium and vanadium have a finer grain structure and are deeper hardening. They are sometimes called Tap steel. K-W steel, of the Carpenter Steel Company, is a keen-edge steel containing 3.5 per cent of tungsten and 1.3 carbon. Sanderson double special steel, of the Crucible Steel Company, has 3.6 per cent of tungsten, 1.30 carbon, and 0.25 chromium. Hard particles of tungsten carbide form in this type of steel, giving high wear qualities. Utica steel, of the Ludlum Steel Company, is an oil-hardening steel which may also be classed as a nondeforming Die steel. It contains 1.4 per cent of tungsten, 1.25 carbon, 0.40 chromium, and 0.20 vanadium. All of these steels have low manganese and silicon. Red Star tungsten, of the Vanadium-Alloys Steel Company, has slightly more tungsten, 1.60 per cent. With 0.90 per cent carbon it is water hardening, and with 1.20 carbon it is oil hardening. It is classed as a keen-edge finishing steel.

**Firebrick.** A term employed to distinguish bricks used in fireplaces, furnace linings, or flues, where ordinary bricks are likely to melt or crack. In the restricted sense firebricks are fire-clay or refractory clays rich in alumina and silica, but low in ferrous oxide, lime, and alkalies. The clay alone is likely to contract excessively and crack, and is mixed with other clays, sand, or graphite. Firebricks are made in various shapes and sizes and are usually white or buff in color. Some other materials used in making firebricks are chromite, bauxite, diatomaceous earth, and magnesite. Artificial materials are usually silicon carbide and aluminum oxide. Common firebricks from natural fireclays will melt at from 2800 to 3100°F. Chromite bricks will

withstand temperatures up to 3700°F., and magnesia brick up to 3900°F. Silicon carbide bricks without a clay binder will withstand temperatures above 4000°F.

**Fireclay.** Clay composed of silicate of aluminum used for linings and furnace parts that must withstand high temperatures. Theoretically these clays contain 45.87 per cent of alumina and 54.13 per cent of silica, but in practice they contain considerable iron oxide, lime, and other impurities. The nearer to the theoretical proportions, the better is the clay as a refractory. Clays with an excess of silica are also found. A noted fireclay is the German Klingenberg clay used for making crucibles. It has about 60 per cent of silica. The term Fireclay embraces nearly all clays having a melting point above 1600°C. See Alumina, Magnesite, Olivine. Firecrete is the trade name of Johns-Manville for a light-weight refractory used for casting concrete for furnace doors and floors. It consists of calcined high-alumina clay, and will withstand continuous operation at 2400°F. Insuline, of the Quigley Company, is a calcined fireclay in small cellular particles. In insulating brick it is called Insulbrix, and as a lightweight concrete it is known as Insulcrete.

**Fish oil.** An oil obtained from the fat of the cod, herring, sardine, salmon, and sprat by boiling the fish and skimming the oil from the surface. The oil is of pale or brownish color and has an offensive odor. The specific gravity is about 0.930. It is of the nondrying class, and used for lubricants, leather dressing, and glues. It is sometimes bleached white. Japan fish oil consists of mixtures of the oils of Japanese sardines and herrings. The American production of fish oil is 13,000,000 gal. annually. Fish meal is the scrap used for cattle feed and fertilizer. Besides its use in lubricating oils, fish oil is employed for oil baths in heat-treating steels. See also Herring oil, Whale oil, Menhaden oil, Blackfish oil, Salmon oil, Sardine oil.

**Flax.** A fiber obtained from the flax, or linseed, plant, *Linum usitatissimum*, used for making the fabrics known as linens, and for thread, twine, and cordage. Flax consists of the "bast" fibers, or those in the layer underneath the outer bark,

which are of fine texture. The fiber is valued because of its beauty, strength, and durability. It is finer than cotton, and the fibers are usually about 20 in. in length. The largest producers are Russia, Belgium, Holland, Italy, Ireland, France, and Egypt. Some flax is grown in the United States, especially in Michigan and Minnesota. The plants that are grown for the seeds, Linseed, yield a poor fiber and are not employed to produce flax. The plants are pulled up by the roots, "retted," or partially decayed, scraped, and the fibers combed out and bleached in the sun. For the best European flax the preparation is entirely by hand. See also New Zealand flax.

**Flint.** An opaque variety of chalcedony which shows no visible structure. Thin plates of flint are translucent. It contains from 96 to 99 per cent of silica and is colored by impurities. It becomes white when calcined, and loses its luster. Flint is finely crystalline, has a hardness of 7, and a specific gravity of 2.6. It was the prehistoric utility material for tools and was later used with steel to give sparks on percussion. Gun flints are still made from a type of flint mined at Brandon, England, for special uses. Flint is used as an abrasive, in pottery and glass manufacture, and in building. Flint paper for abrasive use contains crushed flint in grades from 20 to 240 mesh. It is usually coated on 70- or 80-lb. paper, and sold in sheets or rolls. See Sandpaper. Lydian stone, or Touchstone, is a cherty flint once employed for testing gold.

**Flooring plaster.** Plaster used for flooring, made by the calcination of pure gypsum at a temperature of about 400°F. The gypsum dehydrates at about 190°F. Flooring plaster is free from water and is generally finely ground. It gives a hard and durable surface if protected from water during the setting. It is often mixed with sand. A cubic foot of hardened plaster weighs 120 lb. Hard-finishing plasters contain some alum. See Mack's cement, and Keene's cement.

**Fluorite.** Also called Fluorspar. A crystalline or massive-granular mineral of the composition $CaF_2$, used as a flux in the making of steel, for making hydrofluoric acid, in opalescent glass, in ceramic enamels, and as a binder for vitreous abrasive

wheels. The specific gravity is 3.18, the hardness 4, and the colors light green, yellow, rose, or brown. When ground the color is white. The melting point is 1650°F. Fluorite is mined in Illinois, Kentucky, Nevada, and New Mexico. It is a better flux than limestone, making a fluid slag, and freeing the iron of sulphur and phosphorus. From 5 to 8 lb. is used per ton of steel. The usual grades for fluxing are smaller than 1½ in. High-grade fluorite for ceramic frit has 95 to 98 per cent of Calcium fluoride, and is known as No. 1 ground. It is 100 to 200 mesh. Acid spar is a high grade used in making hydrofluoric acid. Optical fluorspar is the highest grade.

**Flux.** A substance added to a refractory material to aid in its fusion, such as lime for melting iron. A secondary action of a flux, which may also be a primary reason for its use, is as a reducing agent to oxidize or decompose impurities and carry them off as slags or as gases. In soldering, a flux may serve to remove oxides from the surface to be soldered. Materials such as charcoal used to cover baths of molten metals may also be considered as fluxes. See Boroflux. Fluxes for melting iron are lime, limestone, dolomite, or fluorspar. For brass, bronze, or soft white metals, resins may be used; the covering flux may be charcoal, salt, or borax. Fluxing alloys for brasses and bronzes are phosphor-tin, phosphor-copper, manganese copper, or silicon-copper. They deoxidize the metals and sometimes add elements to the alloy. Cryolite is a flux for aluminum and for glass. For tinning steel, palm oil is used as a flux. For ordinary soldering, zinc chloride is a common flux. Tallow, rosin, or olive oil may also be used for soldering. Acetamide is used for soldering painted metal surfaces. For silver solders borax is the common flux; for stainless steel the borax is mixed with boric acid, or pastes are made with zinc chloride and borax. White flux is a mixture of sodium nitrate and nitrite. It is a strong oxidizer and is used for welding. Borax is also used for welding. Welding fluxes are sometimes coated on the rod or contained in the center of the welding rod. Fluxes are marketed under many trade names. Lapix, of the E. F. Houghton & Company, is a powdered mixture of carbon and clay used to cover the top of hot steel after pouring

in ingot molds. It is exothermic and helps to maintain a longer liquid period to enable the deoxidized material to rise to the top. Murex, marketed by the Metal Thermit Corporation, is a welding rod coated with a mineral flux and covered with asbestos. The flux and asbestos form a slag which falls off the weld.

**Fluxing stone.** A common term for the limestone or dolomite used in the melting of iron. Approximately 900 lb. of limestone are employed for every long ton of pig iron produced in the blast furnace. If iron ore were reduced without a basic flux, the silica and alumina would unite with the iron oxides to form double silicates of iron and alumina, and there would be a heavy loss of iron. With the addition of limestone, the silica and alumina, having a stronger affinity for the lime and magnesia, form compounds which contain very little iron. These compounds form a liquid slag which floats on the surface of the molten iron and can be removed readily. The flux also removes sulphur and phosphorus from the iron. Some iron ores contain sufficient lime carbonate to be self-fluxing. Lime is more effective as flux than limestone, but is expensive. The action of the blast furnace is to first convert the limestone into lime. Upon being heated to 1525°F. limestone breaks down to lime, which then melts only at 4660°F., but begins fusion with silica to form a slag at about 2600°F. Limestones for use as flux must be fairly pure, or additional slag and compounds will be formed. See also Dolomite, and Fluorite.

**Fontainemoreau bronze.** This alloy is not a bronze, but is a Reverse brass with zinc predominating. The usual composition is from 90 to 92 per cent of zinc, 7 to 8 copper, with sometimes some lead and iron. The alloy was widely used before the use of aluminum alloys and before the development of the modern zinc-base alloys with less copper. Unless modified with other elements, the alloys are weak and have little ductility. See Gamma brass. But the addition of iron or aluminum increases the strength. The modern development of the alloy for machine bearings incorporates aluminum and sometimes magnesium. One grade of Lumen bronze, of the Lumen Bearing Company, contains 86 per cent of zinc, 9.9 copper, 4 aluminum, and 0.1 mag-

nesium. The tensile strength is up to 45,000 lb. per sq. in., compressive strength 80,000 lb. per sq. in., and Brinell 124.

**Forging brass.** Any alloy of copper and zinc employed for the die-forging of mechanical parts. They usually contain some lead, and frequently some iron. Forging brass of the Chase Brass & Copper Company has 60 per cent of copper, 38.25 zinc, and 1.75 lead. The Mueller Brass Company uses alloys with 56 to 63 per cent of copper, 0 to 3 per cent of lead, and 0 to 3 per cent of tin. With the copper content below 56 per cent the brass is brittle; with copper higher than 63 per cent the wear on dies is high. High-strength brasses are also used for forgings. Durana metal contains 65 per cent of copper, 30 zinc, 1.5 iron, 1.5 aluminum, and 2 tin. Forging brass is called in England Hot-stamping brass, and British standard, B.E.S. 218, calls for 58 per cent of copper, 40.5 zinc, and 1.5 lead. It has a tensile strength of 25 tons per sq. in. and elongation of 28 per cent. Brass forgings made in smooth dies are tough and compact and need no polishing, being simply pickled in a nitric acid bath to bring out the color.

**Formaldehyde.** A colorless, poisonous gas, of the composition $HCOH$, with a boiling point of $-21°C$. It is very soluble in water, and is marketed as a 40 per cent solution under the name of Formalin. Formalin usually contains, however, only 37 to 38 per cent of formaldehyde. It is a clear, colorless liquid with a specific gravity of 1.075 to 1.081. Formalin is obtained by oxidation from methyl alcohol. It is one of the best disinfecting agents, and is also used in making molding compounds and as a reducing agent in the silvering of mirrors.

**Franklinite.** An ore of the metals zinc and manganese. Its approximate composition is $(FeZnMn)O \cdot (FeMn)_2O_3$, but it shows wide variation in the proportions of the different elements. It is found in the zinc deposits of New Jersey. The zinc is converted into zinc white, and the residue is smelted to form spiegeleisen. The mineral franklinite occurs in massive granular structure with a metallic luster and an iron-black color.

**Fuel briquettes.** Various-shaped briquettes made by compressing powdered coal, usually with an asphaltic pitch binder,

but sometimes as Smokeless fuel without a binder. They are sometimes also made waterproof by coating with pitch or coal tar. Fuel briquettes are made from anthracite or low-volatile bituminous coals or mixtures. The bituminous coals require no binders. The usual forms of the briquettes are pillow-shaped, cubic, cylindrical, ovoid, and rectangular, and the usual size is not over 5 oz. They have the great advantage over natural coal in uniformity of firing. The term Packaged fuel is used for cube-shaped briquettes wrapped in paper packages, and used for hand firing. Packaged fuel generally has a binder of starch. See also Charklets. Koal Pak, of the Johnson Coal Cubing Company, consists of coal cubes wrapped 8 in a package.

**Fuel oil.** Distillates of petroleum or shale employed in diesel engines and in oil-burning furnaces. True fuel oils are the heavier hydrocarbons in kerosene, but the light or distillate oils are used largely for heating, and the heavy or residual oils for industrial fuels. See Gas oil and Range oil. In some cases only the light oils, naphtha and gasoline, are distilled from petroleum and the residue is used for fuel oil, but this is wasteful of the lighter oils. Fuel oil of low gravity requires preheating to permit complete atomization. At 10 deg. Baumé the minimum temperature to atomize fuel oil is 300°F., but at 40° Bé. a temperature of only 40°F.is required. Fuel oils used in oil burners are 28 to 32° Bé, and have a B.t.u. content of 142,000 per gal., completely atomizing at 90°F. Ignition temperatures of crude oils vary from 715 to 800°F. in air at atmospheric pressure. Bunker C oil, for diesel engines, is a viscous, black fuel oil of specific gravity 1.052 to 0.9659 with a flash point above 150°F. The National Bureau of Standards lists six grades of fuel oils with flash points from 100 to 200°F.

**Fuller's earth.** A soft, opaque clay with a greasy feel, much used as a filtering medium in clarifying and bleaching fats, greases, mineral and vegetable oils. It absorbs the basic colors in organic compounds. It is also employed as a pigment filler and a substitute for talcum powder. It was formerly much used by textile manufacturers as a "fuller" for woolen cloth, cleansing it by absorbing oil and grease. It is a hydrated compound of

silica and alumina with sometimes ferric oxide. It may contain from 47 to 75 per cent of silica, 10 to 19 of alumina, 1 to 4 of lime, and 2 to 4 of magnesia. The color is greenish brown or greenish gray. The material from Florida and Georgia is Montmorillonite. See Clay. Unlike clay, fuller's earth falls to powder in water. It is marketed dried, or dried and ground. Activated clay, or Bleaching clay, for bleaching oils, may be acid-treated fuller's earth, or China clay, or bauxite. For this use the clays are known as Activated earths, and the adsorptive power is increased by pugging and extruding treatment.

**Fumigant.** A liquid, powder, or gas used in fumigating buildings or ships for killing burrowing animals. The fumigants consist of calcium cyanide, hydrocyanic acid gas, carbon disulphide, sulphur dioxide, or carbon monoxide. Various compounds and mixtures are marketed under trade names, such as Carboxide, of the Carbide and Carbon Chemicals Corporation, which is a mixture of carbon dioxide and ethylene oxide. Fumigants of this nature have the advantage that they do not affect foodstuffs or other stored products. Fumigants are distinct from Repellents, which are used for driving out animals or insects. These consist of compounds containing naphthalene, ammonia, coal-tar products, or lime-sulphur solutions.

**Furfural.** Also known as Furfuraldehyde. It is a colorless liquid with an aromatic odor, employed for making synthetic resins for molding purposes. The composition is $C_4H_3O{\cdot}CHO$. The specific gravity is 1.159 and boiling point is 161°C. On exposure it turns black and gradually decomposes. It is soluble in 11 parts of water. It is made from cornstalks, corncobs, straw, oat husks, and peanut husks by treating under pressure and distilling. Furfural also finds use as a preservative and as a disinfectant. Furfural when heated with aniline at 150°C. forms an insoluble black substance which is used as an enamel. Furfural is also used for blackening other molding resins. Other names for the material are Furol and Pyromucic aldehyde.

Furfural-acetone resin is a synthetic molding material made by the reaction of furfural and acetone in the presence of an alkali. It is a brilliant, transparent, elastic resin, and a patented

resin of this type, under the name of Furfuracetone, is used for making photographic films. Furfural-phenol resin is a molding material made by the reaction of furfural and phenol in the presence of an acid. It can be used like other phenol resins, but its dark brown to black color gives it limited application, although the resin has notably high gloss and precision in molding.

**Fusible metal.** A group of alloys having melting points below the temperature of boiling water, 100°C. They are used as solders or binding plugs in automatic sprinkler systems, for soldering pewter and soft metals, and for filling metal tubing to be bent. They consist generally of mixtures of lead, tin, and bismuth, but some may also contain cadmium. The general rule is that an alloy of two metals has a melting point lower than that of either metal alone. By adding still other low-fusing metals to the alloy a metal can be obtained with any desired melting point. The original Newton's alloy, examined in 1860 by Lipowitz, contained 50 per cent of bismuth, 31.25 lead, and 18.75 tin. Newton's metal, used as a solder for pewter, contains 25 per cent tin, 25 cadmium, and 50 bismuth. It melts at 203°F. Lipowitz alloy, containing 3 parts of cadmium, 4 tin, 15 bismuth, and 8 lead, is very ductile and takes a fine polish. It melts at 158°F. and was formerly used for casting fine ornaments. Small amounts of indium are now added to increase the brilliance and to lower the melting point. It is also used as a solder for Britannia metal. Boiler-plug alloys contain 8 parts of bismuth, from 5 to 30 lead, and from 3 to 24 parts tin. They melt at temperatures from 212 to 342°F. D'Arcet's alloy, used for fire plugs and fine castings and melting at 200°F., contains 50 per cent bismuth, 25 tin, and 25 lead. This alloy expands on cooling and is used for making impressions of dies. See Cerromatrix. Lichtenberg's alloy, melting at 198°F. and used for castings, contains 50 per cent bismuth, 30 lead, and 20 tin. Guthrie's alloy, with the same characteristics, has 47.4 per cent bismuth, 19.4 lead, 20 tin, and 13.2 cadmium. Homberg's alloy contains 3 parts lead, 3 bismuth, and 3 tin, and melts at 251°F. Rose's alloy is quite similar; it has 35 per cent lead, 35 bismuth, and 30 tin. Malotte's metal contains 46 per cent bismuth, 20 lead, and 34 tin; it melts

at 203°F. Alloys with melting points below 100°C. are also sometimes made. A fusible metal with a melting point of 60°C. has 26.5 per cent of lead, 13.5 tin, 50 bismuth, and 10 cadmium. Fusible metals of higher melting points have been used as temperature indicators. Temperite alloys, of the Cornish Wire Company, are alloys of lead, tin, and cadmium, having definite melting points between 300 and 625°F. in steps of 25 deg.

**Fustic.** Known also as Cuba wood. The wood of the tree *Chlorophora tinctoria*, of tropical America, used for cabinet-making and as a dyewood. It has a yellow color, is very hard, and has a fine, open grain. The weight is about 41 lb. per cu. ft. The liquid extract of the wood produces the two dyestuffs Morin, $C_{15}H_{10}O_6$, and Maclurin, $C_{13}H_{10}O_6$. Fustic extracts are mordant dyes and give colors from yellow to olive with various mordants.

**Gallium.** An elementary metal, symbol Ga. It is soft and easily cut, and is soluble in acids. Its melting point is 87°F., softening when held in the hand. Gallium is found in small quantities associated with zinc ores, but is produced chiefly in Germany as a by-product of copper smelting. It has a very high boiling point and is valued for high-temperature thermometers. It is somewhat similar to quicksilver, and is used as a backing for optical mirrors and in dental alloys.

**Galls.** A tanning material obtained from the nutgalls or Gall nuts obtained from the oaks of Europe and from the sumac of China and Japan. Nutgalls are plant excrescences caused by the punctures of insects. They contain 50 to 60 per cent of tannins, and are the richest in tannin of all the tanning materials. Green galls, or Aleppo galls, are from the Near East. Chinese galls are in the form of irregular roundish nuts which enclose the insect. They show no vegetable structure but have a dense resinous fracture. Gall, or Beef gall, is an entirely unrelated material from the gall bladders of cattle, used in making special soaps for washing dyed goods and for fixing dyes in fabrics.

**Galvanized iron.** A general name for steel and iron sheets coated with zinc by dipping in a bath of the molten metal. The

most common sheets are of low-carbon steel. The galvanized iron for culvert sheets may be of pure iron, copper iron, copper-molybdenum iron, copper steel, Bessemer steel, or open-hearth steel. After rolling, the sheets are annealed, pickled, cold-rolled to polish them, and then dipped. Galvanized sheets are resistant to corrosion and are used for roofing and sheathing. They usually come in lengths of 6, 7, and 8 ft., and widths of 24, 26, 28, 32, 34, and 36 in. The thickness is by gage sizes, usually from No. 14 to 30. A No. 14 sheet will carry a 2-oz. coating. Galvanized sheets have a characteristic spangle. The spangle is likely to peel and flake under distortion, and the thicker the coat the greater the peel. Sheets are sold as "primes," "seconds," and "gray coated." Primes are perfect sheets. Seconds are picked out with imperfections of gage, coating, or size. Galvanized sheets are either plain or corrugated. Wire is also galvanized by dipping in molten zinc and is marketed plain or twisted. Zinc alloy steel sheet, of the Inland Steel Company, is zinc-coated steel; instead of a superimposed coat of zinc, the coating is fused in and alloyed with the steel. The coating is smooth and not spangled as in ordinary galvanized steel. It can be spun or drawn without cracking the coating. Gal-Van-Alloy is a trade name of this company for galvanized sheet steel. Bethanized steel is a term applied by the Bethlehem Steel Company to wire electrogalvanized by a special process. Zinc in solution is plated on the wire and the wire passes from the bath through a die which polishes and hardens the coating of zinc.

**Gambier.** An extract obtained from the leaves of the shrubs *Uncaria dacyoneuro*, *U. gambir*, and other species, of India. It is quite similar to catechu. The liquid water-extract contains 25 per cent of tannin; the cube gambier, 35 per cent. The latter is in small pieces. It also comes as a brown, solid mass in large blocks. Gambier is employed in tanning leather and in dyeing to give yellow colors.

**Ganister.** A natural refractory material, which is essentially silica with lime as a binder. A typical analysis is 94.6 per cent of $SiO_2$, 1.4 per cent of $Al_2O_3$, 0.9 per cent of $Fe_2O_3$, 0.44 per cent of CaO, 0.16 per cent of MgO, and 2.5 per cent of alkalies

and water. The principal deposits are the quartzites of Wisconsin, Alabama, and Colorado. The name ganister is also applied to a mixture of about 85 per cent of silica and 15 per cent of clay. Ganister is used chiefly for furnace linings. Ganisand is the trade name of the Quigley Furnace Specialties Company, Inc., for refractory ganister. The fusing point is 3250°F. Dinas silica is an English ganister with about 97 per cent of $SiO_2$, small amounts of $Al_2O_3$ and $Fe_2O_3$, and lime. The melting point is is about 1680°C.

**Garnet.** A large group of minerals used for abrasives, for bearing pivots in watches, and also as gem stones. Garnets are aluminum tri-silicates of lime, magnesia, ferrous oxide, and other substances, together with manganese oxide or chromic oxide. The general formula of garnets is $R_3R_2'(SiO_4)_3$, in which R is Ca, Mg, Mn, or Fe oxide, and R′ is Al, Cr, or Fe oxide. There are thus six general types of garnets. The hardness range is from 6½ to 7½, and the specific gravity is 3.4 to 4.3. The color is most often red, but it may be brown, yellow, green, or black. Garnets occur in a wide variety of rocks in various parts of the world. Owing to the cheapness of the common varieties and the consequent depreciation of the name garnet, the stones that are marketed as gems are always sold under other names. Cape ruby, from South Africa is a red garnet. Most of the garnet produced is used for abrasive paper and cloth. See Abrasive garnet, Almandite, and Pyrope.

**Garnierite.** An important ore of nickel, found in New Caledonia. It is a nickel silicate of approximately the formula $H_2NiSiO_4$. It is amorphous and earthy, with a specific gravity of 2.2 to 2.8 and a hardness of 3 to 4. The color is apple-green or whitish. The ore contains about 5 per cent of nickel, and is smelted in blast furnaces with gypsum, producing a matte containing about 45 per cent of nickel. This is reduced with charcoal and refined.

**Gas oil.** A brownish, oily liquid obtained in the distillation of petroleum and shale oils, used for enriching coal gas for illuminating purposes, as a fuel in heavy oil engines,

and for breaking down to obtain gasoline. It has the odor of kerosene, and a specific gravity of about 0.850. It is obtained from petroleum after the kerosene fraction, above 300°C. It possesses high calorific power, over 18,000 B.t.u., and is free from ash. It contains about 85 per cent of carbon, 13 of hydrogen, and 2 of oxygen. About 40 per cent of some American crude oils is gas oil. Gasol is a yellowish oil obtained by condensing casing-head gas. It is used for enriching fuel gas.

**Gasoline.** Also known in England as Petrol. A product obtained by the fractional distillation of petroleum oils. It is a hydrocarbon between $C_6H_{14}$ and $C_{10}H_{22}$, and distills off between the temperatures 69 and 174°C. Even the best gasolines, however, have the light limit at Heptane, $C_7H_{16}$, or Octane, $C_8H_{18}$. These two fractions are used as standards of measure for detonation, as High-octane gasoline. See also Abietine. Gasoline is a colorless liquid with specific gravity between 0.066 and 0.747, employed chiefly as a motor fuel. It is also sometimes used as a cheap solvent for paints. Commercial gasoline has an upper level as high as 225°C., and an average specific gravity of 0.75. High-test gasoline comes within the correct limits. Aromatic-free gasoline has a specific gravity of 0.718. Five gallons of crude petroleum will usually yield about 1 gallon of gasoline. Natural gasoline is gasoline obtained from natural gas by absorption or by compression. Motor fuel is a general name to include natural gasoline, gasoline produced from oil, or by the hydrogenation of coal tar, from benzol, and any mixtures used in internal-combustion engines. Federal specifications for motor fuel call for a highly volatile hydrocarbon 90 per cent to evaporate at 180°C., 50 per cent at 125°C., and 10 per cent at 65° C., with a maximum of 0.10 per cent sulphur. But the term Motor fuel in other countries usually means substitute mixtures. See Monopolin. Gasanol, used in the Philippines, is a blend of 75 per cent ethyl alcohol, 20 gasoline, and 5 kerosene. The Italian motor fuel called Robur is 30 per cent ethyl alcohol, 22 methanol, with gasoline. The German Dynalkol is 70 per cent gasoline with alcohol and benzol. Synthetic gasoline is produced in Germany by the hydrogenation of brown coal at

high temperatures and pressures. The Bergius process of lignifying powdered coal produces gasoline, an intermediate oil, and a heavy oil.

**Gear bronze.** An indefinite name for any bronze used for casting gears and worm wheels. It usually indicates a phosphor bronze of high-tensile strength, chill cast. A typical bronze of this character contains 88.5 per cent copper, 11 tin, 0.25 lead, and 0.25 phosphorus. This bronze, when cast, has a tensile strength up to 40,000 lb. per sq. in., elongation up to 10 per cent, and a Brinell hardness from 70 to 80, or up to 90 when chill cast. The weight is 0.306 lb. per cu. in. This bronze is the same as S.A.E. No. 65. A Hard gear bronze, or Hard bearing bronze, used by the U.S. Navy contains 84 to 86 per cent of copper, 13 to 15 of tin, up to 1.5 of zinc, a maximum of 0.75 nickel, and up to 0.5 of phosphorus. Another Navy bronze contains 80 to 82 per cent copper, 18 to 20 tin, a maximum of 0.5 lead and 0.1 iron, and 0.3 to 0.6 per cent of phosphorus. It has a tensile strength of 45,000 lb. per sq. in. and Brinell hardness 160. A bronze for worm wheels contains about 87.5 per cent copper, 11 tin, 1.5 nickel, and 0.15 phosphorus. The tensile strength is 51.000 lb. per sq. in., elongation 18 per cent, and hardness 100 Brinell.

**Germanite.** A mineral of a dark reddish-gray color containing no less than 20 elements, but chiefly valuable as a source of the rare metal germanium. The mineral contains about 45 per cent copper, 30 per cent sulphur, 9 per cent germanium, 5 per cent iron, 4 of arsenic, 3 of zinc, and smaller amounts of lead, gallium, silica, titanium, tungsten, molybdenum, manganese, nickel, cobalt, cadmium, magnesium, and carbon. The approximate formula is $10Cu_2S_4GeG_2 \cdot As_2S_3$. It is found in southwest Africa.

**Germanium.** A rare elementary metal found in argyrodite, zinc blende, germanite, teallite, tantalite, and certain other minerals. The chemical symbol is Ge. It is obtained by reduction from its oxides with carbon in a current of hydrogen. It is also obtained as a by-product of the zinc industry. It has a specific

gravity of 5.35, a melting point of 956°C., and is a grayish-white crystalline metal of great hardness and brittleness, being 6.25 Moh. It resembles silicon in its properties. As little as 0.35 per cent of germanium alloyed with tin doubles the hardness of the tin but decreases its ductility 20 per cent. See Argyrodite.

**German silver.** An old name for a group of copper-nickel-zinc alloys with a wide variety of commercial uses. The color varies from white to nickel, and also to yellowish. The metal does not tarnish or corrode easily, and is used for springs and contact points in electrical work. It is also employed as a base-metal for plated silverware. German silver is graded according to its nickel content. Extra white metal, the highest grade, contains 50 per cent of copper, 30 of nickel, and 20 of zinc; the "fifths," for plated goods, contain 57 per cent of copper, 7 of nickel, and 36 of zinc. A ruling of the Federal Trade Commission has been made against the use of the name German silver for alloys containing no silver; the terms Nickel brass, or Nickel bronze, and a variety of trade names are employed. All the early German silvers contained iron, up to 2 per cent, usually as an impurity, but it increased the strength, hardness, and whiteness. Tin makes the alloy brittle, but an early English patent called for 3 per cent iron, 2 tin, 55 copper, 23 nickel, and 17 zinc. This would be considered now as a Nickel casting bronze. See Nickel silver, Nickel brass.

**Gilding metal.** A brass alloy containing 95 to 97 per cent of copper and balance zinc, and employed chiefly for the manufacture of cheap jewelry and small-arms ammunition. It has a reddish-gold color, is stronger and harder than copper, but the electrical conductivity is only little more than half that of copper. The 95–5 mixture is a standard product of the brass mills, but United States government specifications also refer to a 90–10 alloy as gilding metal, and the British engineering standards call for three grades, 80, 85, and 90 per cent copper. The English name Cap copper refers to a gilding metal used for cartridge caps containing 97 per cent copper and 3 zinc. Chrysochalk is an old name given to a gilding metal containing a small

percentage of lead. More expensive high-copper alloys to simulate gold for low-priced jewelry contains some gold and silver. The Japanese, especially, have produced these alloys. Shadke is copper with some gold, and Shaku-do is an alloy of 95 per cent copper, 1 silver, and 4 gold. A similar alloy, called China silver, has 1.5 per cent silver and 4 gold. See also Rich low brass.

**Gilsonite.** A natural pure asphalt found in Colorado and Utah, used for roofing, paving, in rubber compounds, in waterproof paints, and in japans. It is a lustrous, black, brittle mass, having a specific gravity of 1.10, and is practically odorless. It is soluble in alcohol, turpentine, and mineral spirits. Elaterite and Wurtzilite are similar asphalts found in Utah, used chiefly for acid-resisting paints. Grahamite is another asphalt found in large deposits in Oklahoma. It is used in insulation and molding materials and in paints. Manjak is a variety of asphalt from Barbados and Trinidad, used for insulation and paints.

**Glass.** The amorphous solid substance formed by the fusion of silica and a basic oxide. Silica has the power of existing in the amorphous state when solid, and crystallization can be prevented by cooling slowly. Glass is composed of acid oxides such as silica, boric oxide, and phosphoric anhydride, and basic oxides including $Na_2O$ and $K_2O$, and oxides of barium, manganese, magnesium, and other elements. Soda ash is used to prevent fogging of the glass. Feldspar is used in all types of glass as a fixing agent to prevent disassociation of the soda ash and silica. Glass was made in ancient times by fusing sand with an alkali; the Egyptians were famous glass makers. The important properties of glass are its transparency, its rigidity at ordinary temperatures, and its capacity for plastic working at elevated temperatures. Glass is frequently colored with metallic oxides. The composition of glass varies with the use for which it is intended. See Crown glass, Plate glass, Optical glass. Glass is cast, pressed, or blown, and cast glass is often cut by grinding. Glasses for Cut glass contain lead to give them a crystalline brilliancy. Bohemian glass, or Hard glass, is a potash-lime glass with a content of 72 per cent of silica. It grinds and polishes well. Opal glass contains lepidolite. Jena blue glass contains a

mixture of cerium and cobalt oxides. Fluorescent glass for mercury-vapor discharge tubes contains ceric oxide. Glass containing 2 to 4 per cent of ceric oxide absorbs ultraviolet light and is used for application to X-ray exposure. Ruby glass, of a rich red color, is produced with a combination of selenium and cadmium sulphide at high temperature.

Common glass, known as Bottle glass, is composed of silica with soda and lime. Its greenish color is due to the presence of iron. Common Window glass, blown into cylindrical form and then flattened into sheets, is likely to be wavy or bowed in the flattening. Florentine glass is an ornamental glass made by casting on a bed or rolling with a roll on which the designs are cut.

Pure Quartz glass is entirely transparent to ultraviolet light. Flint glass is a highly transparent soda-lime or lead glass, or it may be a pure quartz glass. Lustraglass is the trade name of the American Window Glass Company for a highly transparent white flat-drawn quartz glass. Hydrofluoric acid readily attacks glass and is used for etching it. The density of glass varies from 2.25 for borate glass to 6.33 for the heaviest lead and barium glasses.

Monax is the trade name of the Macbeth-Evans Glass Company for a white diffusing glass used for light shades and architectural glass. Kromex, of the same company, is a glass made to stop the passage of ultraviolet rays. It is used in the cylinders of gasoline-dispensing pumps to prevent change of color in the gasoline. Lumite, of the same company, is a clear crystal glass used for light bowls. Actinic glass, of the Pennsylvania Wire Glass Company, is a glass with an "unsaturated yellow" tint which softens and diffuses the light. It also impedes the passage of heat rays without intercepting the light. It is used for skylights and factory windows. Glass blocks for making translucent units in masonry walls are regularly marketed. Insulux, of the Owens-Illinois Glass Company, is a glass brick of this type. Invisible glass, produced first at the Massachusetts Institute of Technology, is a high-grade Borax glass, surface-treated with a thin film of sodium fluoride. The film measures a quarter of a wave length of green light. The glass transmits 99.6 per cent of light, casting back practically no reflection and thus giving

the appearance of being invisible. Invisible glass, of the Invisible Glass Company, is a highly transparent plate glass, but owes its transparency in show-windows largely to its curved shape.

Highly refractive flint glasses containing lead are used to produce Artificial gems and the so-called Paste diamonds, but the better class of these are not glass. See Artificial gems. The refractive index of glass of this kind is from 1.53 to 1.63, but the double refraction and regular molecular arrangement of true crystals are lacking. Glass gem stones were called Paste gems because of their softness due to the lead.

**Glass cloth.** A name given to cotton fabric made of smooth, hard-twisted yarns which do not lint, and used for wiping glass. It may be of the type known as Sponge cloth, which is a twill fabric of nub yarn or honeycomb effect, or it may be of Terry cloth, which has a heavy loop pile on one or both sides.

**Glass fiber.** The fine, flexible fibers made from glass, used instead of mineral wool for insulation or for fireproof textiles. One of the earliest of these materials used for insulating was the Glass silk produced in England from ordinary glass melted and spun on revolving drums. The fiber is about 0.001 in. in diameter and forms a loose blanket. Glass wool, or Navy wool, is a light-weight insulating material composed of glass fibers made of special glass forced through minute orifices similarly to the method of production of rayon. The fibers range from 0.0007 to 0.00005 in. in diameter and are strong and flexible. The commercial fibers for insulating mats are 0.0004 in. in diameter. Glass fiber for fireproof and insulating Glass fabrics are very flexible and can be twisted and woven in standard textile machines. For this purpose the fibers are below 0.00025 in. in diameter and have tensile strengths up to 400,000 lb. per sq. in. The strength depends more upon correct drawing to reduce discontinuities than upon the composition of the glass, although composition is important for the qualities. Glasses low in alkali have high electrical resistance; glasses with alkali resist acids better. The usual composition is that of a soda-lime glass.

**Glass sand.** Sands employed in glass making. They are all screened, and usually washed to remove fine grains and organic

matter. The grain standards of the American Ceramic Society specify that all should pass through a No. 20 screen, between 40 and 60 per cent should remain on a No. 40 screen, between 30 and 40 per cent should remain on a No. 60 screen, between 10 and 20 per cent on a No. 100 screen, and not more than 5 per cent should pass through a No. 100 screen. Sand for first quality optical glass should contain 99.8 per cent of $SiO_2$, a maximum of 0.1 per cent of $Al_2O_3$, and 0.02 per cent of $Fe_2O_3$. Third quality flint glass may contain only 95 per cent of $SiO_2$, and as high as 4 per cent of $Al_2O_3$. Only in the eighth and ninth quality amber glasses is the content of $Fe_2O_3$ permitted to reach 1 per cent. Potters' sand is usually a good grade of glass sand of uniform grain employed for packing to keep the ware apart.

**Glue.** A cementing material usually made from impure gelatin from the clippings of animal hoofs and hides, sinews, horn pith, or from the skins and heads of fish, or from bones. Good grades of glue are semitransparent, free from spots and cloudiness, and are not brittle at ordinary temperatures. Bone glue is usually light amber in color; the strong hide and sinew glues are light brown. The stiffening quality of glue depends upon the evaporation of water, and it will not bind in cold weather. Albumen glues are made from blood or from casein, and these are much used for fastening plywood. However, they do not have the strength of the best grades of animal glue, especially pure Hide glue. Marine glue is a glue insoluble in water, made from solutions of rubber or resins, or both. See Adhesives. Animal glue has been used since ancient times, and is now employed for cementing wood, paper, and paperboard. It will not withstand dampness, but white lead or other material may sometimes be added to make it partly waterproof. The so-called Casein glues are water resistant, but these are not technically glues. Hide glues are graded in first, second, third, and fourth cookings; the best glues have high viscosity. Glues for such uses as holding abrasive grains to paper must have flexibility as well as strength, obtained by adding glycerin. Fish glue is made from the jelly separated from fish oil, or from solutions of the skins. The best fish glue is made from Russian isinglass. Fish glues do not form gelatine well and are usually

made into Liquid glues. The liquid glues are also made by treating other glues with a weak acid. Pungent odors indicate defective glue; the glues made from decomposed materials are weak. Preservatives such as sulphur dioxide may be used. In use, glues should not be boiled. The melting point is usually about 140°F.

**Glycerin.** Also called Glycerol. A tri-hydroxy alcohol of the composition $C_3H_5(OH)_3$, forming an important constituent of oils and fats from which it is set free during saponification. Glycerin is a colorless, sirupy liquid having a sweet, burning taste. It is soluble in water and in alcohol. It is a by-product in the manufacture of soap, but is also prepared by heating fats in a current of steam or by fermentation methods. Glycerin is used widely in industry. It does not evaporate easily, and is used in articles which require to be kept from drying, such as in stamping inks. It has a low freezing point, 17°C., and a high boiling point, 290°C., and is thus valuable as an antifreeze liquid for automobile radiators. It is also used in making some synthetic molding resins. With litharge it makes a cement used in plumbing. Double-distilled glycerin has a specific gravity of 1.260. Glycerin is marketed crude or distilled.

**Gold.** An elementary metal, symbol Au, known since the most ancient times as one of the precious metals. It is so chemically inactive that it is found mostly in the native state. It is found widely distributed in all parts of the world. It is employed chiefly for coinage, ornaments, jewelry, and for gilding. Gold is extracted by crushing the ores and catching the metal with quicksilver, but about 25 per cent of the gold produced in the United States is placer gold, and about 5 per cent is a by-product of the copper industry. Ore with only 50 cents' worth of gold per ton can be profitably worked by modern methods. Native gold is usually alloyed with silver, placer gold being the purest. The natural alloy of gold and silver was known as Electrum, and under the Egyptian name of Asem was thought to be an elementary metal until produced as an alloy by the Romans. Gold is yellow in color, soft, and is the most malleable of all the metals. It can be beaten into extremely thin sheets. A gram

of gold can be worked into leaf covering 6 sq. ft., and only 0.0000033 in. thick, or into a wire 1.5 miles in length. Cast gold has a tensile strength of 20,000 lb. per sq. in., and drawn gold wire 27,000 lb. per sq. in. The specific gravity is 19.32, and the melting point 1943°F. It is not attacked by nitric, hydrochloric, or sulphuric acids, but is dissolved by aqua regia, or by a solution of azoimide. Because of its softness, gold is almost always alloyed with other metals, usually copper, silver, or nickel, and graded on a basis of degrees of fineness in 1,000 parts, or on the basis of carat gold value, pure gold being 24 carats. Coinage gold in the United States is 90 per cent gold and 10 copper. In England it is 91.66 per cent gold and 8.33 copper, and this alloy is called Standard gold. In Australia 8.33 per cent silver is used instead of the copper, and the Gold-silver alloy is called Australian gold.

Dental gold is a term for a wide range of wrought and cast alloys with usually from 65 to 90 per cent of gold, 5 to 12 silver, 4 to 12 copper, and frequently platinum and sometimes palladium. A very small amount of iridium may also be used for hardening. Colors vary from white to yellow, with tensile strengths up to 125,000 lb. per sq. in. Such alloys are also used for jewelry and ornamental articles. The consumption of gold for industrial purposes in the United States is about 3,000,000 oz. annually; about 2,000,000 oz. are annually recovered from discarded articles. More than half of the world production of gold comes from South Africa. See also White gold.

**Gold shell.** A name used in the jewelry retail trade for a gold-shelled copper alloy employed in cheap jewelry manufacture. It is usually a rich-low brass base metal. See Rich low brass. The slabs are plated with gold and then rolled out into sheets, the amount of gold on the surface being less than 1 per cent of the weight. It is also called Talmi gold and Abyssinian gold. See also Doublé.

**Granite.** A coarse-grained, igneous rock having an even texture, and consisting largely of quartz and feldspar with often small amounts of mica and other materials. Granite is very hard, compact, and takes a fine polish, showing the beauty

of the crystals. It is the most important building stone, and is also used as an ornamental stone. An important use is also for large rolls in pulp and paper mills. It is extremely durable, and since it does not absorb moisture like limestone or sandstone, it does not weather or crack like these stones. The colors are usually reddish, greenish, or gray. Rainbow granite may have a black or dark green background with pink, yellowish, and reddish mottling, or it may have a pink or lavender background with dark mottling. The weight is 170 lb. per cu. ft., the specific gravity 2.72, and the crushing strength is from 23,000 to 32,000 lb. per sq. in. The most notable granite quarries are in northern New England. Mount Airy granite from North Carolina is light gray in color and is a Biotite containing feldspar, quartz, and mica. It is somewhat lighter in weight and of lower crushing strength than Maine granite. The granite known as Pegmatite, of which there are vast quantities, contains beryllium in the form of beryl as a minor constituent.

**Graphite.** Also called Plumbago. It was formerly known as Black lead, and when first used for pencils was called Flanders' stone. A natural variety of elemental carbon having a grayish-black color and a metallic tinge. It occurs in two forms, foliated and amorphous. Foliated graphite is used principally for crucibles and lubricants, and amorphous for lead pencils, foundry facings, electric brush carbons, stove polish, and paint pigments. It is infusible, but oxidizes at about 700°C. It is a good conductor of heat and electricity, is resistant to acids and alkalies, and is readily molded. The hardness is 1 to 2, sometimes less than 1, and it has a decidedly greasy feel. It is a good lubricant, especially when mixed with grease, and for this purpose air-floated Graphite powder is used. It is not affected by high temperatures and is sometimes mixed with molten bronze or babbitt for making self-lubricating bearings, although these are more usually made by sintering. See Graphited metals.

Graphite is found in large deposits in Mexico, India, Ceylon, and in the United States in Alabama and New York. Of the imported, the amorphous comes from Mexico and the crystalline from Ceylon and Madagascar. Natural graphite occurs in veins in rock and always contains some impurities. Some varieties

containing as little as 35 per cent of graphitic carbon are used for paints. No. 1 Flake graphite should contain 90 per cent of graphitic carbon. Mexican Amorphous graphite carries 80 per cent. Crystalline graphite and Flake graphite are really synonymous terms to describe material of high graphite content and as distinguished from amorphous. Molding graphite is a natural graphite ground to extreme fineness, used in foundry work. Combination lead is a term for ground graphite used for foundry facings. Molded graphite brushes for motors and generators may have the graphite mixed with metal powders, and the electric-carrying capacity varies with the metal powder.

Artificial graphite, made in the electric furnace, is preferred for lubricants because of its purity. Colloidal graphite is produced at very high temperatures, about 3000°C., and will withstand this temperature indefinitely in inert atmospheres, although it combines with oxygen in the air above 600°C. The extremely fine particles of colloidal graphite will remain in suspension indefinitely, and it is marketed in distilled water, mineral oil, castor oil, glycerin, or resin varnish, under trade names. Prodag is a solution in water marketed by the Acheson Colloids Corporation for foundry facings. Grafita and Grafene, of the United States Graphite Company, are grease and oil solutions for lubricating purposes.

**Graphited metals.** Graphite and metal or metallic oxide mixtures sometimes erroneously referred to as alloys, used chiefly as bearing metals. There are two general classes, those called bronze and those of the white metal or babbitt type. In general, the materials are produced by diffusing or sintering the powdered materials which have been compressed in molds. Graphited bronze, of the Johnson Bronze Company, contains 40 to 45 per cent graphite, and the remainder metal. A grade of this material is called Ledaloyl. Genelite is a spongy bronze made by heating the powdered oxides of copper, lead, and tin with an excess of graphite, shaping in steel molds under high pressure, and sintering in a furnace. The porosity due to the graphite permits the product to absorb about 20 per cent by volume of oil. The tensile strength is 8,000 lb. per sq. in., and

the compressive strength 50,000 lb. per sq. in. Genelite is a product of the General Electric Company, and is used for bearings and sealing rings. Oilite, marketed by the Amplex Division of the Chrysler Corporation, is an 88-10-2 type of bronze made by briquetting the finely-powdered metals and graphite under high pressure, heat-treating, finishing to size, and impregnating with the lubricant. The oil content averages 35 per cent by volume. It is used as a self-lubricating bearing metal for speeds up to 30,000 r.p.m., and pressures of 6,000 lb. per sq. in. Graphalloy, of the Graphite Metallizing Corporation, is made with either bronze or babbitt metals, and the molten metal is forced into the graphite powder under high pressure. It is marketed in the form of bushings, rods, and tubes. Durex, of the Moraine Products Company, is a diffused material made by sintering the partially reduced oxides of bronze metals with graphite under pressure. The resulting Graphite bronze will take up 29 per cent of its volume of lubricant by capillarity. Gramix, of the United States Graphite Company, is a similar material. Graphex is the trade name of a series of bronze and babbitt graphited bearing metals produced by the Neveroil Bearing Company. The bronze metals have compressive strengths of about 30,000 lb. per sq. in., and the white metals 16,000 lb. per sq. in. In the Boroto metal, produced by E. Siegrist, London, the graphite is in colloidal form, and the metal can be remelted without destroying its qualities. All of the graphited metals can be machined with sharp tools.

**Gravel.** A natural material composed of small, usually smooth, rounded stones or pebbles. It is distinguished from sand by the size of the grain, which is usually above ¼ in., but gravel may contain large stones up to 3 in. in diameter, and some sand. It will also contain pieces of shale, sandstone, and other rock materials. Gravel is used in making concrete for construction, and as a loose paving material. Commercial gravel is washed to remove the clay and organic matter, and screened. Pea gravel is screened gravel between ¼ and ½ in. in diameter. It is used for surfacing with asphalt, or for roofing. Gravel is sold by the cubic yard or by the ton, and is shipped by

weight. Bank-run gravel, with both large and small material, weighs about 3,000 lb. per cu. yd. See also Sand, Crushed stone, Roofing granules.

**Green gold.** The name of a gold-silver-copper alloy employed in making jewelry. Green gold is graded on a basis of carats, the grades varying from 14 to 18, pure gold being 24. The 18-carat green gold contains 18 parts of gold and 6 parts of silver, with no copper. The 15-carat grade contains 15 parts of gold, 8 of silver, and 1 of copper, while the 14-carat grade contains 14 parts of gold, 8¼ of silver, and 1¾ of copper. The higher the gold content, the deeper is the greenish shade.

**Grinding pebbles.** Hard and tough rounded small stones, usually of flint, employed in cylindrical mills for grinding ores, minerals, and cement. Pebbles from Greenland, marketed usually through Denmark and known as Danish pebbles, are of great hardness and toughness.

Quantities of Flint pebbles also come from Denmark for use in tube mills. They are smooth, round pebbles formed by the washing of the sea on the chalk cliffs, and come from the islands off the Danish coast. Danish pebbles are graded in seven sizes, No. 1 being from 1 to 1½ in., and No. 7 from 6¾ to 7⅛ in. American grinding pebbles are from Minnesota, Nevada, and from the beaches of California. Quartzite pebbles are produced in Nova Scotia and Saskatchewan. Granite, rhyolite, and andesite pebbles are also used for grinding. Porcelain grinding balls are made of high-grade resistant porcelain, and are marketed in stock sizes for use in tumbling barrels for grinding and polishing. They have the advantage over flint pebbles of greater uniformity.

**Grindstones.** Sandstones employed for grinding purposes. Grindstones are generally employed for the sharpening of edge tools, and do not compete with the hard emery, aluminum oxide, and silicon carbide abrasive wheels which are run at high speeds for rapid cutting. Grindstones are quarried from the sandstone deposits and made into wheels usually ranging from 1 to about 6 ft. in diameter, and up to 16 in. in thickness. They

are always operated at low speeds because of their inability to withstand high centrifugal stresses. The grades vary from coarse to fine. Good grindstones have sharp grains, without an excess of cementing material that will cause the stone to glaze in grinding. The texture must also be uniform so that the wheel will wear evenly. The hard silica grains are naturally cemented together by limonite, clay, calcite, quartz, or mixtures. Too much clay causes crumbling, while too much calcite results in disintegration in the atmosphere. An excess of silica results in a stone that is too hard. See also Sandstone, Pulpstones, and Oilstones.

**Guayule.** A perennial plant grown in northern Mexico and southern California as a source of a rubber substitute. The plants are small. They mature in 5 years and are cut down and contain in the dry state 14 to 16 per cent of latex. The plant is crushed and pulverized in mills, and the rubber extracted by flotation. The rubber has a high tensile strength and is readily vulcanized like ordinary rubber.

It is softer than true rubber, largely due to the content of natural resins which act as plasticizers. In the low-sulphur compounds it remains permanently tacky, and is thus valued for use as a coating adhesive for the permanently tacky binding tape known as Scotch tape. Guayule is used mostly in combination with other rubber.

**Gum.** A name given in the United States to the wood of the tree *Liquidambar styraciflua*, of the United States and Mexico. It is also called Satin walnut, Red gum, and Sweet gum. In England it is known as California red gum and Hazel pine, although the gum, or Blue gum, of California is from a different tree, *Eucalyptus globulus*. See Gumwood. Gum has a reddish-brown color, is soft with a fine, close grain, and weighs about 40 lb. per cu. ft. It is used chiefly for furniture, but has various other industrial uses, including the making of pulp for book paper. The timber is cut mostly in the Southern states, especially in Louisiana, Mississippi, and Arkansas. Red gum is from the heartwood of mature trees and is reddish brown; Sap gum comes from the outer portion of logs or from young trees and is nearly white.

Nearly 25 per cent of all the hardwood used in the United States is red gum. It has an interlocking grain which gives a fine appearance in veneers, but gives a tendency to warp. Gum is graded according to standards of the National Hardwood Lumber Association from Firsts through Selects to No. 3B Common. Local names for red gum are Southern gum, Sycamore gum, Bilsted, and Star-leafed gum. Cotton gum, or Tupelo, of Louisiana, is from the tree *Nyssa aquatica*, and Black gum, also of the Southern states, is *N. sylvatica*. Tupelo and Black gum are fine textured but with large pores. The heartwood is brownish gray and the sapwood is grayish white. They are tough and difficult to split, and find wide use for such articles as mallets, toilet seats, and bottle cases.

**Gum arabic.** Also called Acacia gum. The gum exudation of the small tree *Acacia arabica*, and various other species of acacia trees of Asia, Africa, and the East Indies, especially the *A. senegal* of the Sudan. It is used for adhesives, for thickening inks, as a binding and filling material for textiles, and for thickening rubber latex. It was the most ancient of adhesives. The trees are wounded and the sap allowed to run out, forming in yellowish, transparent lumps. It is soluble in water but insoluble in alcohol. It is also marketed as a white powder of 120 mesh.

**Gumwood.** The wood of several species of eucalyptus trees native to Australia and Tasmania, but now grown in many parts of the world. The wood is used in construction and for inferior furniture. The Blue gum is *Eucalyptus globulus*, which attains a height of 300 ft. and is grown on the West coast of the United States. The wood is a pale straw color, is hard and tough. It has a twisted grain and shrinks and warps easily, but is very durable. The weight is about 50 lb. per cu. ft., being heavier than southern gum. Salmon gum, from *E. salmonophloria*, has a salmon-red color, is dense and hard, and has a fine, open grain. It is superior and has a great variety of uses. The weight is about 60 lb. per cu. ft. Red gum, from *E. calophylla*, has a yellowish-red color, is strong, tough, and weighs about 45 lb. per cu. ft. The grain is fine, but has gum veins intersecting. See Red gum under Gum and under Acaroid. Other species of

gumwood are marketed under the names of York gum, Jarrah, Blackbutt, Tuart, Karri, and Australian red mahogany.

**Gunmetal.** The common name for a casting bronze containing on an average 88 per cent of copper, 10 of tin, and 2 of zinc. It casts and machines well, and is suitable for making steam and hydraulic castings, valves, and gears. It has a tensile strength of 32,000 to 45,000 lb. per sq. in., an elongation of 15 to 30 per cent, with reduction of area of 12 to 25 per cent. The specific gravity is 8.7, and the weight is 0.315 lb. per cu. in. The Brinell hardness varies from 65 to 74. This alloy is the same as the G bronze of the U.S. Navy. In England it is called Ad miralty gunmetal, and is specified as B.E.S. No. 383 for sand castings. Gunmetal ingot, marketed by H. Kramer & Company, may have the zinc replaced by 2 per cent of lead. Such an alloy is easier to machine but has less strength. The gunmetal used by the Pennsylvania Railroad for armature bearings averages 91 per cent copper and 9 tin. Modified gunmetal contains lead in addition to the zinc. It is used for gears and for bearings. A typical modified gunmetal by William H. Barr, Inc., contains 86 per cent copper, 9.5 tin, 2.5 lead, and 2 zinc. It has a tensile strength up to 40,000 lb. per sq. in., elongation 15 to 25 per cent, Brinell hardness 63 to 72, and weight 0.31 lb. per sq. in. Federal specifications for Leaded gunmetal call for up to 1 per cent of lead and 1 nickel.

**Gunpowder.** Also known as Black powder. An explosive extensively used for blasting purposes, and for fireworks. It was introduced into Europe prior to 1250, and was the only propellant used in guns until 1870. It is now superseded for military uses by smokeless powders which do not leave a residue or erode the gun to such an extent. Black powder also has the disadvantage of deteriorating under atmospheric conditions. Gunpowder is a mechanical mixture of potassium nitrate, charcoal, and sulphur, in the proportions of 75, 15, and 10. More saltpeter increases the rate of burning; additional charcoal decreases the rate. A typical slow-burning powder for propelling rockets contains 54 per cent of saltpeter, 13.4 of sulphur, and 32.6 of charcoal. Commercial black powder comes in grains of

graded sizes and is glazed with graphite. The grain sizes are known as: Pebble powder, large-grain, fine-grain, sporting powder, mining powder, Spanish spherical powder, and cocoa powder. The potential energy of gunpowder is estimated at 340,000 kg.-meters per kilogram of powder, or about 500 ft.-tons per lb. The actual gun efficiency of the powder, however, is from 1/10 to 1/50 of this amount. A temperature of about 2100°C. is produced by the explosion of gunpowder. Blasting powder is divided by du Pont into two grades, A and B. The A powder contains saltpeter; the B powder contains nitrate of soda. The other ingredients are the usual sulphur and charcoal. B powder is not so strong or so water resistant as A powder. but is cheaper and is extensively used. Gunpowder is the slowest acting of all the explosives, and has a heaving, not a shattering, effect. Hence, it is effective for blasting and breaking up stone. Pellet powder is blasting powder made up in cylindrical cartridges for easier use in mining. White gunpowder is a powder in which the saltpeter is replaced by potassium chlorate. It is very sensitive and explodes with violence. It is used only for percussion caps.

**Gurjun balsam.** Also known as Wood oil, and sometimes called East Indian copaiba. An oleo-resin obtained from various species of the *Dipterocarpus* tree, about 50 varieties of which grow in India, Burma, Ceylon, and the Malay Peninsula. It is employed in varnishes and as an adulterant of copaiba. The Burmese trees form two groups yielding products known as "Kanyin" and "In." Kanyin oils are brown in color, while the "In" oils are whitish and heavier. Gurjun balsam may consist of either or both of these products. Commercial gurjun oil is obtained by steam distillation of the balsam, and has a specific gravity of 0.900 to 0.930. It is soluble in alcohol. Copaiba balsam is a resin obtained from the copaifera tree of South America. Maracaibo copaiba and Para copaiba are the principal varieties. They are dark yellow or brown in color, and are soluble in alcohol. The resin is used as a plasticizer.

**Gutta percha.** A gum obtained by boiling the sap of several species of trees of the order *Sapotaceae*, native to Borneo, New

Guinea, and the Malay Peninsula. It is grayish white, very pliable, but not elastic like rubber. It is harder and a better insulator than rubber. Gutta percha, like rubber, will vulcanize with sulphur and form a very hard material. It is used for mixing with rubber, but its chief use is in the covering of insulated electric cables. It is also employed like balata for impregnating driving belts, and for washers and valve seats, and in cements. Gutta percha is imported under trade names.

**Gypsum.** A common mineral consisting of Hydrated Calcium sulphate, $CaSO_4 \cdot 2H_2O$, used chiefly for making plaster. It is also used in Germany for producing sulphuric acid. The color is naturally white, but it is sometimes gray, red, or brown due to impurities. The specific gravity is 2.28 to 2.33, and the hardness 1.5 to 2. The natural calcium sulphate without water of crystallization, is used for paper filler under the name of Pearl filler. It is not as white as the artificial hydrated calcium sulphate, called Crown filler, and used for fine writing papers. A crystalline variety, known as Selenite, occurs in transparent crystals and usually splits easily in thin laminations. A fine-grained, marblelike variety, called Alabaster, is employed in ornamental work and for lamps, vases, and novelties. Much alabaster is produced in Colorado. Travertine, which resembles alabaster but is grained like wood, is a water-deposited lime. Gypsum is also used as a filler in paints, and for making incombustible wallboards. A gypsum board, produced by the National Gypsum Company and used for walls, has 2 per cent of wood fiber incorporated. Gypsum wallboard is light and fire resistant. Macoustic, of the same company, is an acoustical plaster made by a patented process. Gypsteel is a trade name of the Structural Gypsum Corporation for slabs of gypsum containing steel reinforcement, used for fireproof floors and ceilings. Gypsum plaster is used for wall finish and for wall blocks for fire resistance where no load is to be carried. Scott's cement is a lime plaster made by grinding lime with 5 per cent of gypsum plaster. It sets rapidly and is used for inside work. Grainboard is a fireproof gypsum board with an imitation wood grain surface used for walls. See Plaster of Paris, and Keene's cement.

**Hafnium.** An elementary metal, symbol Hf. It is present in the earth in about the same amount as copper, but has as yet no commercial application. The atomic weight is 178.6. All zirconium minerals contain several per cent of hafnium, but it is difficult to separate the two metals, and all zirconium preparations contain some of it.

**Hair.** The fibrous covering of the skins of various animals, used for making coarse fabrics and for stuffing purposes. It is distinguished from wool in having no epidermal scales, and cannot be spun readily, although certain hairs, such as camel hair, are noted for great softness and can be made into fine fabrics. Horsehair is from the manes and tails, and is used as a brush fiber and for making hair cloth. It is largely imported from China and Argentina, cleaned and sorted. The imported hair from live animals is more resilient than domestic hair from dead animals. Brush hair is usually cut 3 to 5½ in. long, but tail hair for making Curled hair for weaving comes in lengths up to 30 in. Cattle hair is taken from dead animals. It is used as a binder in plaster and cements, for hair felt, and to blend with coarse wools. Artificial horsehair, or Monofil, is produced by the same chemical processes as artificial silk, but is a single filament cellulose fiber, instead of a thread of several filaments as in silk. It is used for braids, laces, hair nets, rugs, and pile fabrics. Rabbit hair does not felt, but is used in so-called felt hats. Angora rabbit hair, from France, is mixed in some woolens to give a soft feel. Rabbit hair for hats is called Rabbit fur.

**Hair cloth.** A stiff, wiry fabric with a cotton or linen warp and a filling of horsehair. It is elastic and firm, and is used as a stiffening and interlining material. The colors are black, gray, and white. The fabric is difficult to weave and disintegrates easily, as the hairs cannot be made into a single strand and must be woven separately. Press cloth, used for filtering oils, is made from human hair, which has high tensile strength, resiliency, and resistance to heat. The hair comes from China, usually 6 in. long. Camel hair is sometimes substituted for this use. Hair felt is a matted felt made of animal hair. It is used as an insulating material in walls. It comes in rolls, usually ¼ to 2 in.

thick and in widths 36 and 72 in. For covering cold-water pipes, hair felt is usually surrounded with wool felt.

**Hammer scale.** A common name for the sesqui-oxide of iron formed in the hot rolling or forging of steel and iron. It is used for decarbonizing steel by packing the steel articles in the scale and raising to a high temperature. It is also employed for annealing steel by burying the hot steel in a bed of the scale and allowing it to cool gradually. Hammer scale has the composition $Fe_3O_4$. It has a hardness of 5.5 to 6.5, or about the same as abrasive garnet. It is obtained from forge shops or rolling mills.

**Hard bronze.** A shop name for a casting bronze used for bushings, nuts, and working parts of machines. The composition used by an automotive company for its "general hard bronze" is 88 per cent of copper, 2 of lead, 7 of tin, and 3 of zinc. It makes clean, dense castings, and machines well. It has an ultimate strength of 30,000 lb. per sq. in., and an elongation of 12 per cent in 2 in. The "special hard bronze" used by the same company contains 88 per cent of copper, 10 of tin, and 2 of zinc. It is tough and difficult to machine. It is used for gears and for parts working under heavy pressures. See Bronze.

**Hard rubber.** A name for rubber that is vulcanized hard, and used for molding a variety of mechanical and electrical parts, such as switch bases, handles, tool handles, acid pump parts, and parts for chemical machines. It is also marketed in sheets, rods, and tubes. The amount of sulphur employed to obtain hard rubber may be as great as 33 per cent; the amount determines the hardness of the product. The tensile strength varies from 1,500 to 10,000 lb. per sq. in., depending upon the hardness which varies from 45 to 70 Scleroscope, the usual strength being from 3,500 to 6,500 lb. per sq. in. The specific gravity is 1.11 to 1.4. The dielectric strength is 10,000 to 38,000 volts per mm. Hard rubber, when highly vulcanized, is fragile, but may contain factice to reduce the brittleness. Ordinary commercial grades can be machined readily. It resists the action of organic oils, but mineral oils soften it. Vulcanite is an old name for hard rubber. See Rubber.

**Heat insulators.** Materials employed for retarding the passage of heat rays. All substances offer some resistance to the passage of heat (See table in Appendix), but the term refers to materials having high resistance to heat rays, or low conductivity. Heat insulators may be such materials as felt, fiberboard, cork, or mineral wool, used for insulating partitions in buildings, and their efficiency may partly depend upon dead-air spaces or cellular construction. High-heat insulators, for insulating boilers or furnaces, may be highly refractory substances such as chromite, magnesia, fireclay, or asbestos. Hot pipe lines are usually insulated with 85 per cent magnesia block and asbestos cement. Cold lines usually have a hair felt covering finished with asbestos cement or asphalted felt. Metals which are good conductors of heat will act as heat insulators to reflect back the radiant heat waves, which are normally about 95 per cent of the total heat loss. These are called Reflective insulators. Crumpled aluminum foil is used in this way as a wall insulator. See Alfol. Ferro-Therm, of the American Flange & Mfg. Company, Inc., is a steel sheet, 0.006 in. thick, coated with a white-metal alloy, used for house and refrigerator insulation. Ludlite board, of the Ludlum Steel Company, is a panel board consisting of thin stainless steel backed with a fireproof composition of cement, magnesite, and asbestos fibers. Insulite is a wood fiber insulating board made by the Insulite Company. Asbestos sheathing, felt pads, and special fiberboards are often marketed under trade names. Roofinsul is a light-weight insulation board composed of wood fibers compressed into board form, marketed by Johns-Mansville for roof decks. Ceilinite, of the same company, is an asbestos felt reinforced on one side with asbestos cloth, made in thickness from $\frac{3}{32}$ to $\frac{1}{4}$ in. and used for interlining in steel cars and for fireproofing electrical switch boxes.

Alumino-Hi-Temp, of the Philip Carey Company, is alumina reinforced with asbestos fibers, made in the form of blocks and bricks. Fibrox is a patented soft fibrous material used as a heat-insulating filler. It is a Silicon oxycarbide, SiCO, prepared by diffusing carbon monoxide and carbon dioxide through molten silicon. The fibers are light and fluffy. Dry-Zero, of the Dry-Zero Company, is an insulating material made from the

fiber of the seed pods of the ceiba tree. See Kapok. The carded fiber batt is encased in fiberboard for use in refrigerated cabinets. The low-temperature heat insulators may also be employed to retain the cold in refrigerating systems. Relative heat transmission of various construction materials, as given by the Armstrong Cork and Insulation Company, are: corkboard 1, wood 3.36, concrete 15.47, brick 17.15, and steel 1,036. These are calculated on the basis of the transmission through wood of 1.82 B.t.u. per hr. per bd. ft. for 1°F. difference in temperature between the two sides. Balsam wool, of the Wood Conversion Company, is an insulating material consisting of wood fibers chemically treated and cemented together into fleecy wool form.

**Heat-resistant alloys.** Nickel-chromium-iron alloys containing usually from 5 to 80 per cent of nickel, 13 to 25 per cent of chromium, and the balance iron, which will not scale when exposed to high temperatures. Some of the alloys may contain only nickel and chromium, but more frequently all three metals are used. However, some of these alloys may also contain aluminum, silicon, or other elements. They are used for heat-treating boxes, furnace parts, and machine parts exposed to high heats. The alloys will also resist oxidation and the action of many acids, and are used for chemical equipment. Cromax, of the Driver-Harris Company, contains 35 per cent of nickel, 15 chromium, and the balance iron. It has a tensile strength of 60,000 lb. per sq. in. It is used for temperatures up to 1900°F. Veriloy, of the same company, is a grade of nickel-chromium alloy for medium temperatures. Nichrome, of the same company, is the trade name of a group of alloys for various uses. The standard grade for castings contains 67 per cent of nickel, 16 chromium, 12 iron, and 1 manganese. It has a tensile strength of 64,000 lb. per sq. in. at 20°C. and of 30,000 lb. per sq. in. at 800°C., and will resist oxidation up to 1800°F. for long periods. Such an alloy is tough but will machine readily. Q-Alloy, of the General Alloys Company, is the name of a large group of nickel-chromium-iron heat-resistant and corrosion-resistant alloys in grades to suit various conditions.

Amsco alloy is a series of nickel-chromium and nickel-chromium-iron alloys of the American Manganese Steel Company, and Mackenite metal is a similar series of the Duncan Mackenzie Sons Company. Cyclops No. 17, of the Cyclops Steel Company, contains 20 per cent nickel, 8 chromium, 0.75 manganese, 1.5 silicon, and 0.45 carbon. At a temperature of 1200°F. it has a tensile strength of 75,000 lb. per sq. in. For high load-carrying ability at high temperatures as much as 30 per cent of chromium is used. Lebanon No. 48 contains 30 per cent chromium, 30 nickel, 0.40 carbon, and the balance iron. Allegheny 55, of the Allegheny Steel Company, has 23 to 30 per cent chromium, 1 manganese, and 0.25 carbon. Castings have a tensile strength of 80,000 lb. per sq. in. Nichroloy, of the Hiram Walker & Sons Company, contains 23 per cent of nickel, 20 chromium, 1 manganese, 1 vanadium, and 0.50 aluminum. It will withstand continuous temperatures up to 2000°F. Zorite, of the Michigan Products Corporation, contains 35 per cent nickel, 15 chromium, 1.75 manganese, and 0.50 carbon. The alloys with manganese have low coefficients of expansion. Allegheny 48 is a complex alloy. It has low chromium, 4 to 6 per cent, with low manganese, but may contain 0.40 to 0.60 molybdenum, 0.75 to 1.25 tungsten, and 0.50 to 1.0 copper, with sometimes titanium or columbium in an amount equal to 10 times the carbon content. The tensile strength is 60,000 lb. per sq. in., elongation 30 per cent, and Brinell hardness 170. It is used for superheater parts, oil-still tubes, and chemical tanks for hot gases and chemicals. Ascoloy is the trade name of the Allegheny Steel Company for chromium alloys. Firearmor is the name of the Michigan Products Corporation for heat-resistant alloys. A typical grade contains 60 per cent nickel, 20 chromium, 1.75 manganese, and 0.50 carbon. Fahralloy, of the Southern Manganese Steel Company, is the name of chromium-nickel-iron alloys in various grades to withstand temperatures up to 2200°F. Fahrite alloys are produced by the Ohio Steel Foundry Company. Hybnickel, of the Pusey and Jones Corporation, is made in various grades. A heat-resisting alloy containing silicon is Pyrasteel, of the Chicago Steel Foundry Company. It has 25 per cent nickel, 14 chromium, and 2.5 to 3 silicon, and

will withstand temperatures up to 2000°F. It is also wear resistant. A Chromium-aluminum-iron alloy, under the name of Fecraloy, is marketed by the Wilbur B. Driver Company. It contains 15 per cent chromium, 5 aluminum, and the balance iron. It is used for resistance wire to withstand temperatures up to 1400°F. and is noted for high electrical resistance. See Resistance wire. Tungsten or molybdenum may also be added to heat-resistant iron alloys. Clebrium is an alloy having 3.5 per cent of molybdenum, 13 chromium, 2 nickel, 1.5 silicon, 0.75 manganese, and some carbon. Tungsten and aluminum heat-resisting steels are used for engine valves. See Aluminum steel.

**Heat-resistant glass.** Glass which will withstand high temperatures, or rapid changes of temperature, without shattering. It is usually a boro-silicate glass which is heat-treated and leached in an acid bath, leaving a porous high-silica material that can then be fired to a solid mass, 96 per cent pure silica. The best heat-resistant glasses can be used at temperatures up to 1000°C., and can be plunged into cold water from a red heat without injury. Such glasses are used for chemical equipment and for cooking utensils. Pyrex, of the Corning Glass Company, used for cooking utensils, will withstand temperatures up to 1100°F., and is also shock resistant. The specific gravity is 2.25, hardness 120 Scleroscope, and refractive index 1.4754. It has a light transmission higher than that of plate glass. Duran glass, developed by the Janaer Glaswerke Schott, is used for hot chemical tubes and pipes, and can be quenched with cold water from 150°C. without cracking. In general, the heat-resistant glasses contain $B_2O_3$ and a small amount of alumina, with the smallest possible amount of alkali.

**Helium.** A colorless, odorless, elementary gas having a specific gravity of 0.1368. Because of its extreme lightness and noninflammable quality it is valued for filling balloons, but it is also employed in electric lamps and radio tubes because of its high heat conductivity, which is six times that of air. The lifting power is 92 per cent that of hydrogen. For use in advertising signs it gives a pinkish-violet light when an electric current is passed through it. The liquefying point is about

−269°C. Helium can be obtained from atmospheric nitrogen, but comes chiefly from natural gas, the natural gas of Texas yielding 0.94 per cent. The bulk of the production is from Government-owned plants. Helium is claimed to be the "alpha rays" given off in the decomposition of radium. It occurs in Cleveite and was first discovered in this mineral in 1895. Helium is used chiefly in lighter-than-air aircraft.

**Hemlock.** The wood of the coniferous tree *Tsuga mertensiana*, of the northeastern section of the United States. This species is also called Mountain hemlock, and is now scarce. Western hemlock, *T. heterophylla*, known also as West Coast hemlock, is a wood produced in abundance from Alaska to northern California. The stand of the tree is estimated at more than 140 billion bd. ft. in the United States, of which 85 billion is in Washington and Oregon. The wood is light in color, with a pinkish tinge, light in weight, moderately soft, and straight grained. It is nonresinous and is free from resin ducts, but black knots are frequent. The select grades of the lumber are free from knots and suitable for natural and paint finishes. The wood is used for general construction, boxes, and woodenware. Hemlock-bark extract is obtained from the bark of the eastern hemlock, and was formerly an important tanning material for leather, but in spite of the high tannin content western hemlock bark is not in general use for tanning.

**Hemp.** A fiber widely used as a material for cordage, rope, and sacking. It comes from the stalk of the plant *Cannabis sativa*, grown chiefly in southern Russia, the Mediterranean countries, and Asia, but also cultivated in the United States. The fiber, which is obtained by retting, is longer than that of the flax plant, being up to 75 in., but is coarser and is not suitable for fine fabrics. It is also more difficult to bleach. It is stronger, more glossy, and more durable than cotton, but for marine cordage it has been largely replaced by abaca, which is lighter and more resistant to water. The finest fibers are from the Italian hemp. The plant also contains a toxic alkaloid; in India the stalks are chewed for the narcotic effect. Hempseed oil is made by pressing the seeds. It has a specific gravity

of about 0.926, iodine value of 148, and is used in paints and varnishes. See also Manila hemp, Sisal, Sunn hemp.

**Herring oil.** A fish oil obtained by extraction from several species of herring, the commercial oils coming usually from the Norwegian herring, *Clupea harengus*, or from the Japanese herring, *C. pallasi*. It is employed as a quenching oil in heat-treating, either alone or mixed with other oils. It is not suitable as a drying oil for paints or varnishes, as it does not give an elastic skin. The oil contains a number of fatty acids, chiefly linoleic, oleic, and palmitic. The specific gravity is 0.920 to 0.930. The iodine value is as high as 140, and saponification value 191. Herring oil is made clear and odorless by hydrogenation.

**Hexalin.** An organic solvent of the composition $C_6H_{12}O$, made by the hydrogenation of phenol. It is an excellent solvent for fats, oils, and resins, and is also used as a substitute for turpentine. Hexalin is a solid with a specific gravity of 0.947, melting point 25°C., and boiling point 161°C. It is soluble in 28 parts of cold water and can be mixed with alcohol in all proportions.

**Hexamine.** A white, crystalline powder used chiefly for the manufacture of synthetic resins in place of formalin and its sodium hydroxide catalyst. It is formed by the action of formaldehyde and ammonia. It is hexa-methylene-tetramine, having the formula $(CH_2)_6N_4$, and is very stable when dry. It is readily soluble in water and in alcohol. It is also known as Formin, Cystogen, Aminoform, and Cystamine. Condensite, a molding resin of the Continental-Diamond Fibre Company, is a patented reaction product of phenol and hexamine.

**Hexa-nitro-diphenylamine.** A high explosive employed by the Germans in torpedoes because of its high shattering effect. It was sometimes mixed with 30 to 40 per cent of dinitrotoluene, which makes a more fusible product and detonates with great violence. It is a yellow powder of the composition $C_6H_5 \cdot NH \cdot C_6H_4(NO_2)_3$. Its melting point is 242°C., at which point it then decomposes. It is made from picryl chloride and aniline. It is highly poisonous, causing painful blisters and inflammation.

**Hickory.** The wood of the tree *Hicoria ovata*, and several other species of the walnut order. It is prized as a wood for ax, pick, and other tool handles, and also for wheel spokes, carriage shafts, and golf clubs. The color varies from white to dark brownish. It has a fine, even, and straight grain, and is tough and elastic. The weight is 45 to 52 lb. per cu. ft. The chief producing states are Arkansas, Louisiana, Mississippi, Tennessee, and Kentucky. For handle manufacture the white wood and the red wood are considered equal in physical properties, and both possess the smooth "feel" required for handles. The average specific gravity when kiln-dried is 0.79, compressive strength perpendicular to the grain 3,100 lb. per sq. in., and shearing strength parallel to the grain 1,440 lb. per sq. in.

**Hides.** A commercial name generally signifying the skins of full-grown beef cattle. Kips and Calfskins are the names given to the hides of the younger animals. Hides of other animals besides the beef cattle, *Bos taurus*, are usually designated with the name of the animal, as Horsehide. The hides of smaller animals are designated as Skins, either tanned or untanned, as Pigskin. Hides are shipped in immense quantities from India, Argentina, Uruguay, and other pastoral countries, and made into leather. They are shipped either dried or salted, and are distinguished by numerous grades depending upon the class of animal, method of skinning, and the preparation. Packing-house hides, well skinned, and packed in brine, are the best. The poorest grade is the country hide, taken off by inept knives and dried in the sun. The texture of steer hides is more uniform than cow or bull hides, and the area is greater, permitting more economical cutting. See Leather.

**High brass.** Sometimes called Common brass, and formerly known as Market brass. The most common of all the commercial wrought brasses. The usual mill standard is 65 per cent of copper and 35 zinc, and grades containing from 66 to 70 per cent of copper are referred to as Deep-drawing brass. High brass is marketed in sheets, rolls, and strips, and is used largely for drawing, forming, and spinning. In the hard tempers it is used for parts made by blanking, forming, and bending. It is a cold-work-

ing material and is not suitable for hot-working. The 65–35 brass marketed by the American Brass Company under the name of Yellow brass has a tensile strength of 45,000 lb. per sq. in. and elongation of 60 per cent when soft, and a strength of 76,000 lb. per sq. in. and elongation of 5 per cent when hard rolled. The weight is 0.306 lb. per cu. in., melting point 930°C., and coefficient of expansion 0.0000106. Bar stock, for turned parts, is sometimes designated as high brass, but invariably this material contains lead to make it free machining, as true high brass is tough and turned chips do not break easily. The High brass bar used by the Westinghouse Electric & Manufacturing Company contains 2.25 to 3.25 per cent of lead. The alloy listed in Federal specifications as Commercial brass for wrought shapes actually covers the brasses from muntz metal to high brass, and is leaded. It contains 60 to 65 per cent of copper, with lead permissible up to 3.75 per cent. The Government specifications for Commercial brass for castings are equally broad. Butt brass, for hinges, has 64 per cent of copper, 35 zinc, and 1 lead. The term Etching brass refers to the temper rather than to the composition. It is a high brass sheet in quarter-hard or half-hard temper used for name plates and dials. Bobierre's metal is an old name for 63–37 high brass. This alloy is called in England Basis brass, and is B.E.S. No. 265. Bristol brass and Prince's metal are old names for high brasses with from 60 to 75 per cent of copper. See Leaded high brass and Brass.

**High-lead bronze.** Bronze alloys containing high percentages of lead to give a soft matrix metal for bearing use, as distinct from bronzes containing small amounts of lead to make them free machining. The first high-lead bronze was invented in England in 1870 under the name of Dick's bronze, and was used on British railways. In 1892 C. B. Dudley in the United States produced ExB metal containing 77 per cent of copper, 15 lead, and 8 tin. It is still used as a car bearing metal and called Car brass. A common type of Leaded bronze used for bearings is the 80–10–10 mixture, and this alloy is also known as Ordnance bronze. It has a Brinell hardness of 58, a tensile strength of 30,000 lb. per sq. in., and when deoxidized with phosphorus has

a dense structure. Lead does not alloy well with copper unless a catalyzer is present, and also tends to sweat out at a temperature of 327°C. High-lead bronze is now invariably deoxidized with phosphorus, or contains small amounts of nickel, arsenic, or some other element to aid in "holding up" the lead. The alloys containing tin are true bronzes, and are not as difficult to cast as the copper-lead alloys. Some lead bronzes also contain antimony, which gives them a good crystalline structure useful for bearings. They are easy to cast. Retz alloy and Reith alloy contained about 75 per cent of copper, 10 each of tin and lead, and 5 antimony.

Cyprus bronze contains 65 per cent of copper, 30 lead, and 5 tin. A typical leaded bronze is alloy No. 6, of William H. Barr, Inc. It contains an average of 78 per cent of copper, 8 tin, and 14 lead. The tensile strength is 28,000 to 32,000 lb. per sq. in., compressive strength up to 100,000 lb. per sq. in., and Brinell hardness 54 to 70. The weight is 0.335 lb. per cu. in. Johnson Alloy No. 29, of the Johnson Bronze Company, for electric motor bearings, is the same as S.A.E. No. 67, and contains 78 per cent of copper, 15 lead, and 17 tin. Lubrico, of the Buckeye Brass Mfg. Company, contains 75 per cent of copper, 20 lead, and 5 tin. Sabeco metal, of the Fredericksen Company, has 21 per cent of lead and 9 tin. Sumet bronze, of the Sumet Corporation, is the trade name of a group of bearing bronzes in grades from the softest with 28 per cent of lead and Brinell hardness of 30 to 33, to the hardest with 17.5 per cent of lead and hardness of 58 to 62 Brinell. Arctic bronze, of the National Bearing Metals Corporation, is the name of leaded bearing bronzes chill cast in metal molds to give fine grain structure. Bearium, of the Bearium Metals Corporation, is the name of a group of high-lead bronzes containing 17.5 to 28 per cent of lead and about 10 per cent of tin. The softest grade, with a hardness of 35 Brinell, has a compressive limit of 7,800 lb. per sq. in. Durbar bronze, of the Buffalo Die Cast Corporation, has 24 per cent of lead and 4 tin. Durbar hard bronze has 10 per cent of tin and 20 lead.

Allan red metal is a copper-lead alloy with 50 per cent of lead and a small amount of sulphur to hold the lead in solution. See Copper-lead alloys. Allen's metal was an early alloy containing 40 per cent of lead, 55 copper, and 5 tin. Part of the lead was put

in in the form of galena ore or lead sulphide. Johnson bronze No. 25, used for high-speed bearings, contains 75 per cent of copper, 19 lead, 5 tin, and 1 nickel. High-lead bronzes are resistant to acids and, when used for casting chemical machine parts, are called Antiacid bronze. Leaded bronzes are marketed under many other trade names such as Kalif metal, of the Kalif Corporation.

**High-speed brass.** A name sometimes applied to brass containing a small percentage of lead. It is free cutting, and can be machined easily at higher speeds than common brass. See Leaded high brass. The copper alloy marketed under the name of Hy-speed by the Buckeye Brass and Manufacturing Company, is for high-speed bearings, and is a composition bronze containing about 88 per cent copper, 7 tin, and 5 zinc.

**High-speed steel.** A general name for high-alloy steels which retain their hardness at very high temperatures and are used for metal-cutting tools. They are now divided into three general classes. The tungsten steels form the oldest class and are an outgrowth of the older mushet steels. See Mushet steel. They are divided into two general grades according to tungsten content, with 18 and 14 per cent of tungsten, respectively. The Super high-speed steels, or Cobalt steels, are high in tungsten but contain considerable quantities of cobalt. They have added red hardness but are inclined to be brittle. The third class of Molybdenum high-speed steels are an outgrowth of an early attempt by the U.S. Ordnance Department to substitute molybdenum for the imported metal tungsten. The first Watertown Arsenal steel contained about 9.5 per cent of molybdenum, 4 chromium, 1.25 to 2 tungsten, 0.90 to 1.5 vanadium, 0.80 carbon, 0.20 to 0.40 manganese, and 0.25 to 0.50 silicon. Molybdenum has a more pronounced effect than tungsten in a ratio of 2 to 1, but it makes the steel more brittle and also makes it subject to decarburization. The standard tungsten steels are therefore sometimes modified with very small amounts of molybdenum. ML steel, of the Ludlum Steel Company, has 18 per cent of tungsten, 4 chromium, 1.85 vanadium, and 0.50 molybdenum. It gives a keener edge than the standard 18 per cent tungsten steel.

The standard for tungsten high-speed steels is the 18–4–1. containing 18 per cent of tungsten, 4 chromium, and 1 vanadium, This steel gives a balance of red hardness, toughness, and cutting edge; in England preference is for the 14–4–2, which gives higher hardness and resistance to wear. Tungsten adds red hardness to steel; chromium gives deep hardening and increases toughness; and vanadium gives hardness and improves the ability to keep an edge. Cobalt gives added red hardness, but the steels are more difficult to forge and are more brittle. The property of red hardness is described as the ability of the steel to retain the hard carbides up to a temperature of about 1750°F. The cobalt alloys that have this property but contain little or no iron are not classed as high-speed steel. See Cutting alloys.

High-speed steels are marketed in rods, bars, flats, and tool shapes. They are sold under many trade names, such as Supremus and Jessco, of the Jessop Steel Company, Clarite, of the Columbia Tool Steel Company, Rex, Champion, and Peerless, of the Crucible Steel Company, Colonial, of the Colonial Steel Company, Blue Chip, of the Firth-Sterling Steel Company, Panther, of the Ludlum Steel Company and Kutkwik, of Henry Disston & Sons, Inc. Electrite uranium, is a special brand of Electrite steel of the Latrobe Electric Steel Company, containing some uranium, which is a more powerful deoxidizer and hardener than vanadium. Star-Zenith, of the Carpenter Steel Company, is an 18–4–1 steel with elements in slight excess of standards.

Motung steel, patented by the Cleveland Twist Drill Company, contains 7.5 to 8.5 per cent of molybdenum, 1.25 to 2 tungsten, 3.5 to 4.5 chromium, 0.90 to 1.5 vanadium, 0.80 carbon, 0.20 to 0.40 manganese, and 0.25 to 0.50 silicon. The name Mo-Tung is used by the Universal-Cyclops Steel Corporation for this steel. Other trade names for the steel when manufactured by other companies are Mogul, Tatmo, Mo-Cut, Vul-Mo, Mohican, LMW, Rex T-Mo, and HM steel.

Circle C steel, of the Firth-Sterling Steel Company, contains 9 per cent of cobalt, 18.5 tungsten, 1.75 vanadium, 1 molybdenum, and 0.77 carbon. Gray Cut Cobalt steel, of the Vanadium-Alloys Steel Company, has 20.5 per cent of tungsten, 4.25 chromium, 1.3 vanadium, 12.25 cobalt, 0.60 molybdenum, and

0.80 carbon. Red Cut Cobalt, of this company, and Co-Co steel, of the Colonial Steel Company, are 18–4–1 steels with the addition of 4.5 per cent of cobalt and a small amount of molybdenum. Maxite, of the Columbia Tool Steel Company, is an 18–4–2 steel with 4 per cent of cobalt. Rex AA steel, of the Crucible Steel Company, is an 18–4–1 steel, while Rex AAA is this steel with 5 per cent of cobalt and 0.50 molybdenum. Milvan steel, of A. Milne & Company, has 19 per cent of tungsten with 4 chromium and 2 vanadium.

**High-test cast iron.** A term originally applied to cast iron that was superheated in the melting for pouring, poured in chilling molds, and then heat-treated. The only change in composition in such an iron is to keep the silicon and manganese high. In general, high-test cast iron is iron so prepared as to give a careful balance of ferrite, pearlite, sorbite, cementite, iron phosphide, and graphite, and the resulting iron somewhat resembles malleable iron, and tensile strengths above 50,000 lb. per sq. in. are obtained. But the name has now come to be applied also to any high-strength cast iron made with steel scrap, or with nickel, molybdenum, chromium, and other elements that give strength to the metal but are not in sufficient amounts to classify the iron as an alloy cast iron. All of the high-test cast irons are fine-grained, and are not spongy like ordinary cast iron; the qualities may be obtained either by the treatment or by alloying elements, or both. Steel scrap gives a stronger and finer structure. Nickel gives ease of machining and aids in the chilling. Chromium gives hardness and resistance to growth. Molybdenum raises the combined carbon and adds strength and hardness. High-test cast irons are used for brake drums and for high-strength and wear-resistant castings. They are marketed under many trade names.

Ermal is a pearlitic cast iron of the Erie Malleable Iron Company used for heavy-duty gears, brake drums, and fittings. The tensile strength is up to 70,000 lb. per sq. in. Pearlit is a pearlitic iron of the Durson Corporation. Aremite is a "synthetic cast iron" of Robbins and Myers, Inc. Jewell alloy, of the Jewell Steel and Malleable Company, is a group of high-strength and

heat-resistant irons in varying degrees of hardness. Ermalite, of the Erie Malleable Iron Company, has a Brinell hardness of 240 and a tensile strength up to 65,000 lb. per sq. in. A somewhat similar iron is Wear-loy, of the Frank Foundries Corporation. Gunite, an alloy of the Gunite Corporation, is called Graphitic steel, and is used for cams, rolls, and worm gears. The carbon is distributed in even flakes. The total carbon is below 3 per cent, and the silicon is 2 per cent. The normal tensile strength is 35,000 lb. per sq. in., but when quenched to a hardness of 477 Brinell it has a compressive strength of 200,000 lb. per sq. in. Meehanite metal, produced under license of the Meehanite Research Institute of America, is made in a wide range of high-strength, wear-resisting, corrosion-resisting, and heat-resisting castings for dies, hydraulic cylinders, brake drums, pump parts, and gears. The normal tensile strengths range from 35,000 to 55,000 lb. per sq. in., compressive strengths from 135,000 to 175,000 lb. per sq. in., and hardnesses from 193 to 223 Brinell. Oxygenized iron is a patented high-test cast iron made by blowing iron through a part of the metal and then returning the oxidized metal to the cupola.

**Holly.** The wood of the tree *Ilex aquifolium*, and several other species of *Ilex*, or holly tree, native to Europe, and the tree *I. opaca*, of the United States. It is valued as a wood for inlaying because of its white color and fine, close grain. It is rather hard, and the weight is 47 lb. per cu. ft.

**Hopcalite.** A name given to a gas-absorbent material employed to provide protection against carbon monoxide from explosions, automobile exhaust, and the "after damp" in coal mines. It consists of a granular mixture of oxides of copper and manganese to which the oxides of silver and cobalt are sometimes added. This mixture oxidizes carbon monoxide, which is not stopped by ordinary gas masks with charcoal and soda lime.

**Horn.** The excrescent growth, or horns, from the heads of certain animals, notably beef cattle. Horn is used for making handles and various articles. The quality depends largely upon the size and age of animal from which it comes, the No. 1 grade

being the large steer horns, and the No. 2 those below 40 lb. per hundred. Horns occur on the head in pairs and are hollow, growing on a core of pithy bone. The horns are split by saws, soaked to make them flexible, and then flattened under pressure. Horn meal is made from the bone refuse, and is sold largely as fertilizer. Horn pith, extracted by boiling the horns, is used for glue and for edible gelatine.

**Hot-die steel.** A general name for alloy steels that will resist shock and retain their hardness when operating in forging machines at high temperature. When used in hot-heading machines they are also called Hot-work steels. Two types of these steels are commonly employed, one type being a chromium steel with 3 to 4 per cent of chromium, or in another grade with about 8 to 10 per cent; and the other type being a tungsten steel with 8 to 10 per cent of tungsten. The molybdenum high-speed steels are also used for hot-die work. See Mo-Tung. The chromium steels are oil hardening and develop a high hardness. They are deep hardening but will withstand shock. The tungsten steels have higher impact value, and are superior for severe service at high heats such as for hot punching or for brass extrusion, but they are more expensive. The chromium steels are used for dies for compressive action, as for header machines. The higher tungsten steels give full red hardness, but they are not hard enough for cutting dies. Nickel and vanadium may also be added to hot-die steels, giving increased hardness and toughness. The self-hardening high-tungsten steels containing high manganese and carbon are not classed as hot-work steels. See Maxtack steel and Manganese steel.

Mohawk steel, of the Ludlum Steel Company, is a hot-die steel containing both tungsten and chromium. Its composition is about 14 per cent tungsten, 3.5 chromium, and 0.70 vanadium, with 0.45 carbon. Atlas steel, of this company, contains 9 to 11 per cent of tungsten, 3.25 to 3.60 chromium, and small amounts of vanadium. Crescent steel, of the Crucible Steel Company, has 3.75 per cent of chromium and 0.95 carbon. Peerless A, of this company, has 9 per cent of tungsten, 3.25 chromium, and 0.25 vanadium, and is used for die-casting dies, extrusion dies, and

gripper dies. C.Y.W. steel, of the Firth-Sterling Steel Company, has 3.5 per cent of chromium and 1 carbon. D.Y.O. steel, of the Carpenter Steel Company, has 14.5 per cent of tungsten, 4 chromium, and 0.50 vanadium. Excelo, of this company, has 2.5 per cent of tungsten, 1.5 chromium, 0.35 vanadium, and 0.55 carbon. It is used for hot shears. Vasco Marvel steel, of the Vanadium Alloys Steel Company, has 9.25 tungsten, 3.5 chromium, and 0.45 vanadium. Vasco Extrude Die is a combination of the two types. It has 15.5 per cent tungsten, 3 molybdenum, 4 chromium, 2 nickel. The hot-die steel produced by the Heppenstall Company under the name of Hardtem is a nickel-chromium steel with molybdenum and vanadium. E.H.W. steel is a tungsten hot-work steel of the Latrobe Electric Steel Company. Peerless steel, of the Crucible Steel Company, is in several grades of tungsten-chromium-vanadium. Such steels as Tungo, of the Colonial Steel Company, and Par-Exc, of the Vanadium Alloys Steel Company, with lower tungsten and chromium and some vanadium, are not high heat resistant but are suitable for die-casting dies, and because of their resistance to shock are used for hot upsetting dies. See also Shock-resistant steel.

**Hydraulic bronze.** A shop name for any casting bronze or brass used for pump parts, cocks, and valves. A recommended high-pressure hydraulic bronze is given as 72.5 per cent of copper, 19.25 per cent of zinc, 1.75 of tin, and 6.5 of lead. This alloy is in reality a leaded brass. It casts well and machines freely. Steam bronze is usually an 85–5–5–5 brass. See Composition brass. Nickel is used to densify bronze for hydraulic and steam castings, and make the lead more soluble in the alloy. One company uses a bronze for casting lubricators and injectors, containing 84.5 per cent copper, 5 lead, 7 zinc, 2.5 tin, and 1 nickel. The nickel, added to the melt in the form of nickel shot, contains some silicon. See Nickel brass. Heavy hydraulic castings to withstand water pressure up to 2,000 lb. per sq. in. have been made with the silicon content as high as 7 per cent. A cast bronze containing 88 per cent copper, 6.5 silicon, 1.5 lead, 3 zinc, and 1 nickel, has a tensile strength of 42,000 lb. per sq. in. and elongation 25 per cent.

**Hydraulic lime.** When lime contains other substances, such as silica and alumina, and is hydrated, it has the power of setting and hardening under water. It is a class of natural cement and is also called Hydrated lime, or lime chemically satisfied with water or "slaked." Limestone with more than 10 per cent of silica will give a hydraulic lime on calcination. This lime will show no action for about 15 min. when slaked with water, and then will take upwards of 14 days to slake. It will set under water in 15 to 20 days. Some French limestones contain 20 to 22 per cent of silica and 2 of alumina, and hydraulic cement is made in France and Belgium by burning these limestones. The lumps of slaked lime are finely ground and are known as Grappier cement. Some of the white cements sold under trade names, such as Le Farge, belong to this class. See also Lime.

**Hydrochloric acid.** Also called Muriatic acid, and originally called Spirits of salt. An inorganic acid used for pickling and cleaning metal parts, and also for a variety of industrial applications. It is a water solution of Hydrogen chloride, HCl, and is a colorless or yellowish fuming liquid, with pungent, poisonous fumes. The specific gravity of the gas is 1.269, the solidifying point −112°C., and boiling point −83°C. It is made by the action of sulphuric acid on sodium chloride, or common salt. The commercial acid is usually 20°Bé. equaling 31.45 per cent of HCl gas, and has a specific gravity of 1.16. Fuming hydrochloric acid has a specific gravity of 1.19, and contains about 37 per cent of hydrogen chloride gas. Hydrochloric acid is shipped in glass carboys.

**Hydrocyanic acid.** Also called Prussic acid and Hydrogen cyanide. A substance of the composition HCN, which is a liquid at temperatures below 26°C., but is so volatile at ordinary temperatures that it is considered as a gas. It has a wide use in the laboratory, is used in military poison gases, and as a fumigant. It is so poisonous that death may result within a few seconds after it is taken into the body. It was used as a poison by the Egyptians and Romans, who obtained it by crushing and moistening peach kernels. The specific gravity is 0.697, as a gas. It is soluble in water and in alcohol, and is usually marketed in water

solutions of 2 to 10 per cent. It is obtained by distilling a solution of potassium cyanide and sulphuric acid. The French war gas known as Vincennite was hydrocyanic acid mixed with stannic chloride. Manganite was a mixture with arsenic trichloride.

**Hydrofluoric acid.** A water solution of Hydrogen fluoride, HF. It is a colorless, fuming liquid, highly corrosive and caustic, and is employed for cleaning the sand from iron castings and also for etching glass. Instead of attacking the iron like other pickling acids, it dissolves the sand from the iron. The specific gravity of the gas is 0.713, and boiling point −19°C. It has a strong, pungent odor. Hydrofluoric acid is made by treating calcium fluoride or fluorspar with sulphuric acid. It is shipped in lead carboys or in composition bottles.

**Hydrogen.** A gaseous element, symbol H. It is colorless and highly inflammable. It is used for producing the oxy-hydrogen flame for welding, and also to produce a nonoxidizing atmosphere for heat-treating steels. It is also employed for the hydrogenation of oils and for the production of ammonia. Oils and gasoline can be produced from coal by treatment with hydrogen. Hydrogen liquefies at −252°C. The specific gravity is 0.0695. Its lightness makes it useful for filling balloons, but is largely replaced for this purpose by the noncombustible helium gas. It is produced by the electrolytic dissociation of water, or by the action of water on an alloy of magnesium and lead, or is produced by passing steam through incandescent carbon, then catalyzing the carbon monoxide and separating the carbon dioxide. It comprises about one-ninth of all water and is found in all organic material. It is marketed compressed in cylinders.

**Hydrogenated oils.** Vegetable or fish oils that have been hardened or solidified by the action of hydrogen in the presence of a catalyst. Partial hydrogenation also clarifies and makes odorless some oils. Finely divided nickel is generally used as the catalyst. The solidifying process is carried on to any desired extent, and these oils have a variety of uses. For mechanical uses they are employed in cutting oils, and in place of palm oil in tinplate manufacture. By hydrogenation the fatty acids, such as

oleic acid, are converted into stearic acid. Peanut oil, coconut oil, and cottonseed oil can thus be made to have the appearance, taste, and odor of lard, or they can be made like tallow, though they do not have the vitamin content or food value of lard. Lard compound, previous to the passage of the Food and Drugs Act of 1906, was cottonseed oil mixed with oleo stearin from beef tallow. It was later sold under trade names, but has now been replaced by hydrogenated oils under trade names. Hydrogenated oils have lower iodine values and higher melting points than the original oils.

**Ilmenite.** The most common ore of the metal titanium. It is an iron-black mineral having a specific gravity of about 4.5, and containing up to about 52 per cent of Titanic oxide, $TiO_2$. A white pigment is made from ilmenite by removing the iron oxide. Ilmenite has the composition $FeO \cdot TiO_2$, but much of the material called ilmenite is Arizonite, $Fe_2O_3 \cdot 3TiO_2$, or mixtures, or both mixed with magnetite. The ilmenite for white pigment comes chiefly from the sea beaches of southwestern India. The mineral is also employed in making ferrotitanium used for adding titanium to steel. See also Amang.

**Indian gum.** Also called Karaya gum. The gummy exudation of the *Astragalus gummifer* and other species of Asiatic plants. It is marketed as a white odorless powder or in flake form. It forms mucilaginous solutions and is used in adhesives and for thickening rubber latex.

**Indigo.** Once the most important of all vegetable dyestuffs. Commercial blue indigo is obtained from the plants *Indigofera tinctoria*, and several other species, of India and Java, and the plant, *Isatis tinctoria*, of Europe, by steeping the freshly cut plants in water, and after decomposition of the glucoside Indican, $C_{14}H_{17}O_6N$, the liquid is run into beating vats where the indigo separates out in flakes which are pressed into cakes. About 4 oz. of indigo are produced from 100 lb. of plants. Indigo red, or Indirubin, $C_{16}H_{10}N_2O_2$, is a crimson dyestuff obtained in the proportion of 1 to 5 per cent in the manufacture of indigo. Indigo White is obtained by reducing indigo red with reducing

agents and an alkali. Indigo is valued for the beauty and permanence of color. It is now made synthetically.

**Indium.** A metallic element, symbol In, discovered first in zinc blende in 1863. It is more silvery-white than tin, and is valued as a plating metal because of its fine color and corrosion resistance. Indium-plated light reflectors are highly efficient. See also Lipowitz alloy. Indium is soft, ductile, and not easily oxidized; above its melting point, it oxidizes easily and burns with a brilliant violet flame. The melting point is 155°C. and specific gravity 7.36. The metal usually remains alloyed with the zinc in the reduction of zinc from its ores. Indium oxide is used to give a beautiful yellow color to glass.

**Ingot iron.** Nearly chemically pure iron made by the basic open-hearth process and highly refined, remaining in the furnace 1 to 4 hr. longer than the ordinary time, and maintained at a temperature of 2900 to 3100°F. In England, it is referred to as Mild steel, but in the United States the line between iron and steel is placed arbitrarily at about 0.15 per cent content of carbon. Ingot iron has as low as 0.02 per cent of carbon. It is obtainable regularly in grades 99.8 to 99.9 per cent pure iron. Ingot iron is cast into ingots and then rolled into plates or shapes and bars. It is used for construction work where a ductile, rust-resistant metal is required, especially for tanks, boilers, enameled ware, and for galvanized culvert sheets. The tensile strength, hot-rolled, is 48,000 lb. per sq. in., elongation 30 per cent, and Brinell hardness 82 to 100. "Dead soft," the tensile strength is 38,500 lb. per sq. in., elongation 45 per cent, and Brinell hardness 67. Armco ingot iron, of the American Rolling Mills Company, is 99.94 per cent pure, with the carbon 0.013 and the manganese 0.017 per cent. It is used as a rust-resistant construction material, for electromagnetic cores, and as a raw material in making special steels. The specific gravity is 7.858, and melting point 1530°C. Enamelite is a sheet iron especially suited for vitreous enameling, produced by the Sharon Steel Hoop Company. Ingot iron may also be obtained in grades containing 0.25 to 0.30 per cent of copper, which increases the corrosion resistance. See Copper steel. Plastiron, of Henry Disston & Sons, Inc.,

is a very low carbon iron used for molds and dies which are to be hobbed. The iron is quite plastic under the hob and is then hardened by carburizing.

**Ink.** Colored liquids, or liquids containing finely divided precipitate in suspension. Black writing inks usually contain tanno-gallate of iron obtained by adding an infusion of nutgalls to a solution of ferrous sulphate. This is one of the most ancient methods of ink making. The pyrogallol in gall nuts gives a bluish-black precipitate and produces violet to black inks depending upon the strength of the solution. Gum is added to inks to keep the precipitate in solution. Glycerin is added to copying inks to retard the drying. Aniline dyes, indigo, or mixtures give tints to both black and colored inks. Logwood, chromium, vanadium, and aniline black inks are not resistant to light. Brazil wood, cochineal, and other organic substances are also used in inks. Carbon inks are composed of lampblack with glue, gums, or solutions of gluten. Printing inks are lampblack, boneblack, barite, or other pigments suspended in linseed oil and resin oils. Invisible, or invisible-writing, inks, called Sympathetic inks, are made with salts of metals made visible by heat, or by the application of another chemical such as a solution of lead acetate to be developed with hydrogen sulphide. Indelible ink for marking textiles has silver nitrate and ammonium hydroxide in water solution mixed with sodium carbonate and gum arabic. It resists alkali washing.

**Insulating oils.** Oils of high dielectric strength and high flash point, employed in circuit breakers, switches, transformers, and other electric apparatus. Mineral oils are used for this purpose. The flash point must be high enough to prevent fire or explosion. An oil with a flash temperature of 285°F. and fire point of 310°F. is considered safe. A clean, well-refined oil will have a minimum dielectric strength of 22,000 volts, but the presence of as low as 0.01 per cent of water in the oil will reduce the dielectric strength drastically. The insulating oils, therefore, cannot be stored for long periods because of the danger of absorbing moisture. Any impurities, such as acids or alkalies, also detract from the strength of the oil. Insulating oils are used

for cooling as well as for insulating, and the viscosity should be low enough to permit free circulation. They should not gum.

**Insulators.** Any materials that retard the flow of electricity, and used to prevent the passage or escape of electric current from conductors. No materials are absolute nonconductors; those rating lowest on the scale of conductivity are therefore the best insulators. Glass and porcelain are the most common line insulators because they are cheap, hard, and not affected by moisture. Hard rubber, fiber, synthetic resins, slate, and stone slabs are the usual insulators for panel boards and apparatus. Mica is used as an insulating separator, but it must be free from traces of iron. Various varnishes, resin solutions, and asphalt mixtures are used as insulating impregnating compounds for covering wires or metals. They are also used to impregnate paper or cardboard to make insulating sheet materials. A typical insulator of this type is Armite, of the Spaulding Fibre Company, Inc., which consists of impregnated fish paper in thicknesses from 0.004 to $\frac{1}{8}$ in. The dielectric strength is 500 volts per mil, and tensile strength 8,500 lb. per sq. in. lengthwise. It is used in motors and transformers. Vulcoid, of the Continental-Diamond Fibre Company, is a laminated fibrous material impregnated with a thermoplastic resin. Vulcabeston, of Johns-Manville, is an electric insulating material made of asbestos with a binder of rubber. It is fibrous and can be molded into various shapes. The softening temperature is 175°C. An important requirement of a good insulator is that it will not absorb moisture which would lower its resistivity. Mineral oils are insulators and are used in control boxes. See also Heat insulators and Sound insulators.

**Invar.** The name of a nickel-iron alloy having a very low thermal expansivity. It was developed in France. The expansion is so low that for measuring purposes, under ordinary conditions, it is generally taken as zero. This is taken as 0.0000004 per deg. C.; above 120°C. the coefficient rises. It is used for the measuring guides of accurate instruments and for parts of clocks and watches. A typical composition is: iron 63.5 per cent, nickel 36 per cent, manganese 0.5 per cent. It melts at 2597°F. Invar is also very resistant to corrosion. The yield point is up to 60,000

lb. per sq. in., tensile strength up to 85,000 lb. per sq. in., elongation 25 to 50 per cent, and Brinell hardness 160. Nivar is another name for an alloy of the same composition. Super-Invar is a Japanese product containing 5 per cent of cobalt to replace an equal amount of nickel. It has a nearly zero coefficient of expansion at ordinary temperatures. Nilvar, of the Driver-Harris Company, used for instrument parts, measuring tapes, and connections through glass, is in various grades with about the same coefficient of expansion as glass or with the zero expansion of invar. Low-expansion steel is a name given to iron-nickel alloys, with from 30 to 60 per cent of nickel. See Low-expansion alloys.

**Ionium.** The parent substance of the metal radium. It is found in all minerals and rare earths that contain uranium and radium. It is so similar in all properties to the element thorium, that it is not possible to separate it from thorium when the two have become mixed. Ionium is obtained from uranium ores by fractioning the rare-earth constituents, but the resulting preparation contains the radio-inactive thorium. Ionium gives out the alpha rays of radium and has some of the uses of radium, but it is the most expensive of all materials. It has been used in minute quantities in spark-plug wire. The Symbol is Io.

**Iridium.** A grayish-white metal of extreme hardness, symbol Ir. It is insoluble in all acids and in aqua regia. The melting point is 4260°F., and specific gravity 22.42. The annealed metal has a hardness of 172 Brinell. Iridium is found in its natural state in alloy with the metal osmium, known as Osmiiridium, used chiefly for making fountain pen points. Iridium is employed as a hardener for platinum, the jewelry alloys usually containing 10 per cent. It is sold by the troy ounce, a cubic inch of the metal weighing 11.82 troy ounces.

**Iron.** The most common of the commercial metals. It has been in use since the most remote times, but it does not occur native except in the form of meteorites. The common iron ores are magnetic pyrites, magnetite, hematite, and carbonates of iron. See Iron ores. To obtain the iron the ores must be fused to drive off the oxygen, sulphur, and impurities. The melting is

done in a blast furnace directly in contact with the fuel and with limestone as a flux. The latter combines with the quartz and clay, forming a slag which is readily removed. Iron is a grayish metal, which until recently was never used pure. It melts at 1525°C., and boils at 2450°C. Even very small additions of carbon reduce the melting point. It has a specific gravity of 7.85. All commercial irons except ingot iron and electrolytic iron contain perceptible quantities of carbon, which affect its properties. See Cast iron, Pig iron, Wrought iron, Malleable iron, Ingot iron, and Electrolytic iron. Iron containing more than 0.15 per cent of chemically combined carbon is termed steel, and when the carbon is increased to above about 0.40 per cent, the metal will harden when cooled suddenly from a red heat. See Steel. Iron, when pure, is very ductile, but a small amount of sulphur, as little as 0.03 per cent, will make it "hot short," or brittle at red heat. As little as 0.25 per cent of phosphorus will make iron "cold short," or brittle when cold. Iron forms carbonates, chlorides, oxides, sulphides, and other compounds. It oxidizes easily under atmospheric conditions and is also attacked by many acids. The Reduced iron, used for special chemical purposes, is a fine gray amorphous powder made by reducing iron oxide by heating in a stream of hydrogen. See also Iron sponge.

**Iron ores.** Iron-bearing minerals from which iron can be extracted on a commercial scale. The chief iron ores in order of importance are hematite, magnetite, limonite, and siderite. The greatest producers are United States, France, Russia, Great Britain, and Germany. More than 90 per cent of the iron ores mined in the United States are red hematites, $Fe_2O_3$, containing theoretically 70 per cent of iron, but usually not over 60 per cent. The districts include the Lake Superior region and northern Alabama. It is also the ore from the Furness district in England and parts of Spain and Germany. The color is various shades of reddish brown, and the structure is usually earthy. The variety known as Kidney ore is columnar with a fibrous appearance; Specular hematite has a brilliant luster and foliated structure. The specific gravity is 4.8 to 5.3. Pulverized hematite is used as a paint pigment under the name of Indian red. Brown hematites

contain from 35 to 55 per cent of iron. See Limonite. Ores containing more than 50 per cent of iron are considered high grade. The hematite ores are preferred for the Bessemer process because of their freedom from phosphorus and sulphur. Natural iron is the percentage of iron in the ore before drying, and Dry iron is the percentage of iron in the ore after drying at 212°F. Magnetite, or Magnetic iron ore, is found in northern New York, in New Jersey, and in Pennsylvania. It has the composition $FeO \cdot Fe_2O_3$, containing theoretically 72.4 per cent of iron but usually only about 62 per cent. The ore mined in Norway and Sweden is very pure, and it is the ore used for the celebrated Dannemora iron made with charcoal as a fuel. Magnetite may also contain some nickel or titanium. The specific gravity is 5.18, melting point 1540°C., the color iron-black with a metallic luster, and it is strongly magnetic. The natural magnet known as Lodestone is magnetite. Siderite and carbonate ores are used in Great Britain, Germany, and Russia, much of which is not considered commercial in the United States, but the Dogger iron ore of Germany contains as high as 35 per cent of iron. The world supply of high-grade ores is placed at 30 billion tons, of which 80 per cent is located in Brazil, United States, Newfoundland, and Cuba, in the order named. See also Chateaugay iron, Mayari iron, Siderite. The nearest approach to a native iron is the iron-nickel mineral Awaruite, $FeNi_2$, found in gravel in New Zealand and Alaska, and Josephinite, $FeNi_3$, found in serpentine in Oregon.

**Iron pyrite.** A common mineral sometimes mined for the zinc, gold, or copper associated with it, but chiefly used for making sulphuric acid and copperas. It is an Iron disulphide, $FeS_2$, containing 53.4 per cent of sulphur. If often occurs in crystals, also massive or granular. It is brittle, with a hardness of 6 to 6.5 and a specific gravity of 4.95 to 5.1. The color is brass-yellow, and it is called Fool's gold because of the common error made in detection. Pyrite is found in rocks of all ages associated with different minerals. It was formerly roasted to obtain the sulphur, and the residue, known as Blue Billy, was used as iron ore. The pyrites mined in Missouri, known as Marcasite, also

used for gemstones, have the formula FeS, and the gem specimens have a yellow color with a greenish tinge.

**Iron shot.** An abrasive material made by running molten iron into water. It is employed in tumbling barrels and also in the cutting and grinding of stones. Steel grit is made by forcing molten iron through a steam jet. The metal forms into small globules and irregular pieces of chilled iron. The regular globules are screened and graded into Steel shot in sizes from No. 6 to No. 35, and the irregular pieces and large globules are crushed into Steel grit and graded into sizes from No. 8 to No. 80. It is preferred to sand for sandblasting some materials. Steelblast is the trade name of the Steelblast Abrasives Company for this type of material for tumbling and sandblasting.

**Ironwood.** A name for several varieties of wood, and may refer to any exceedingly hard wood that is used for making bearings, gears, tool handles, or parts of machinery. In the United States ironwood is most likely to refer to Hackia, the wood of the hackia tree, *Ixora ferrea*, of the West Indies, and of tropical South America, or it may refer to the wood of the quebracho tree. Hackia is brown in color, has a coarse, open grain, and is very hard and tough. The weight is about 55 lb. per cu. ft. It is also used for furniture. See also Quebracho. The Burmese tree, *Mesua ferrea*, furnishes the wood Gangaw, which is also known as ironwood. It is a tough, extremely hard wood of a rose-red color weighing 70 lb. per cu. ft.

**Isinglass.** The common name for colorless sheets of mica when used as a transparent material for stove doors. See Mica. The name is more correctly applied to a very pure gelatin made from the dried swimming bladders of sturgeon and other fishes. Russian isinglass is the most valued grade and is one of the best of the water-soluble adhesives. It is used in glues and cements, in printing inks, and in finishing silk. This isinglass is known chemically as Ichthyocolla.

**Ivory.** The material which composes the tusks and teeth of the elephant. It is employed mostly for ornamental parts, such as the keys of pianos. The color is the characteristic ivory-white,

which yellows with age. The West Coast of Africa, India, and Southern Asia are the chief sources of ivory. The tusks of the hippopotamus, walrus, and other animals, as well as the fossil mammoth of Siberia, also furnish ivory, although of inferior grades. Ivory can be sawed readily, and is made into thin veneers for various ornamental uses. It takes a fine polish. Artificial ivory is usually celluloid or synthetic resins. The specific gravity of ivory is 1.87. See also Vegetable ivory.

**Ivory nut.** The source of Vegetable ivory, which is used for making various small articles, mostly buttons. The ivory nut is the seed of the low-spreading palm tree, *Phytelephas macrocarpa*, which grows in tropical America. The nuts are about 2 in. in diameter, growing in clusters and encased in shells. They have a fine white color and an even texture. They can be worked easily and harden on exposure to the air. They take dyes readily and show fine polished colors.

**Japan.** A name applied to black baking enamels. The same finish in other colors would not be called japan. Japan consists of a pigment, a gum, a drying oil, and a reducer in the same manner as any oil enamel. It is always baked. See Lac. The general process is to drive off the solvent by heat and fuse the gum into a uniform vitreous layer. Japans are used to give a tough durable finish to small machine parts, but synthetic enamels are now largely substituted because a more uniform gloss can be obtained without the between-coat rubbing necessary with japan.

**Japan wax.** A fat of the coconut-oil group used largely for adulterating beeswax. It is a vegetable fat contained between the kernel and outer skin of the berries of plants of the genus *Rhus*, which grow in Japan and also cultivated in California. The fat, which is misnamed wax, is extracted by steaming and pressing the berries, and is refined by melting and pressing through cotton cloth. Japan wax is greenish yellow and melts at 51°C. The specific gravity is about 0.975. It contains chiefly palmitic acid. The saponification value is about 220. It is sometimes adulterated with common tallow. Lac is a variety of Japan wax

obtained from the sumach plant, *R. vernicifera*, of Japan and Korea. It is used as a drying oil in baking enamels and for transparent lacquers. It is a gum exudation of the wood, and not obtained from the berries. Lac is not to be confused with shellac from the lac insect. See Chinese lacquer.

**Jet.** A hard and compact, dense, black lignite, which can be cut and turned in the lathe and will take a fine polish. It was formerly much used for making buttons, toys, and ornamental articles, but has been largely replaced by synthetic resins. It is found in Colorado and in Europe.

**Jute.** A fiber employed for making burlap, sacks, cordage, ropes, and upholstery fabrics. It is obtained from an order of plants of India, of which *Corchorus capsularis*, is the most widely cultivated, growing in a hot, steaming climate. Most of the commercial jute comes from Bengal. The plant grows in tall slender stalks like hemp, and the fiber is obtained by retting and cleaning. The fiber is long, soft, and lustrous, but is not as strong as hemp. It also loses its strength when damp, but is widely used because of its cheapness and because of the ease with which it can be spun. The crude fiber may be as long as 14 ft., but the commercial fibers are from 4 to 8 ft. The "butts," or short ends of the stalks, and the rough fibers, are used for paper stock. Jute paper, used for cement bags, is a strong paper made of these fibers usually mixed with old rope and old burlap in the pulping. It is usually in tan color.

**Kalsomine.** An old name for wall paint made with whiting and glue and some linseed. Water colors are added to produce tone effects. Water paints for walls, sold under various trade names, are usually varieties of kalsomine. Whitewash is a cheap white paint made from slaked lime, salt, whiting, and glue, or sometimes quicklime and water alone. These paints will not withstand severe weathering.

**Kangaroo leather.** A strong, supple, and durable leather made from the skins of the Australian kangaroo, used chiefly for shoe uppers and gloves. The skins measure from 2 to 12 sq. ft. in area, and the small ones are known as Wallaby. The fibers

have an interwoven structure, and the leather does not scuff easily. It takes a brilliant polish. It is rated as the strongest shoe leather per unit of weight.

**Kaolin.** Also called China clay. A pure form of hydrated Aluminum silicate clay. There are three distinct minerals, Kaolinite, Nacrite, and Dickite, all having similar composition. The formula for kaolin is usually given as $Al_2O_3{\cdot}2SiO_2{\cdot}2H_2O$, but is more accurately expressed as $Al_2Si_2O_5(OH)_4$. It occurs in claylike masses of specific gravity 2.6, and of a dull luster. Kaolin is used for making Porcelain, or Chinaware, as a refractory for bricks and furnace linings, for electric insulators, as a pigment and filler in paints, as a filler in plastics, and as an abrasive powder. In firebricks it resists spalling. Its melting point is 3200°F., but this lowers with impurities. It is a decomposition product of granite and feldspar, and its usual impurities are quartz, feldspar, and mica, which can be washed out. Kaolin is white, but inferior qualities burn to a yellow color. It should never contain iron. The Cornwall kaolin of England and the Limoges kaolin of France are the best known. English china clays contain little or no iron oxide, and the yellow clays contain only organic materials which can be bleached out. The best grade of English clay is used for coating and filling paper. Cornish clay, known as China stone, is used for the best grades of porcelain glazes. Cheaper grades of kaolin, called Mica clay, are used for earthenware glazes, and as an absorbent in oil purifying. The clay of Kentucky and Tennessee, known as Ball clay, occurs in massive beds of great purity, and the clay has high plasticity, good bonding strength, and is light in color when fired. It is used for high-grade porcelain and for wall tiles. Impure varieties of kaolin, called Kaolinic earth, are used for refractories. Halloysite has about the same composition as kaolinite but contains more alumina and water. It occurs with kaolinite. In association with alunite in Arkansas it is called Newtonite. Some varieties, such as Glossecollite, are waxlike. Indianaite, or Allophane, is an impure halloysite. It is a white, waxy clay found in Indiana, and is used for pottery. The Indiana halloysite used for refractories is called Malinite. When kaolin is employed as an inert

colloidal pigment with zinc oxide, it is called Chinese white. It is insoluble in water. Bone clay is a pure kaolin from feldspar and granite. It makes a strong porcelain. But Bone china is a name given to high-grade English pottery made with china clay and 25 per cent of calcined bone. Flesh clay is formed from feldspar and quartz. It gives resilience to the porcelain. Clays can be proportioned to give desired characteristics. Hartporzellan is a German porcelain having a high resistance to temperature changes. It is marketed in tube form for conveying hot chemicals. Thyrite is the trade name of the General Electric Company for a specially compounded porcelain which possesses the property of being an insulator at low potentials and a conductor at high potentials. It is used for lightning arresters. Micronized clay is a name for pure kaolin ground to a fineness of 400 to 800 mesh, used as a filler in rubber. Dixie clay, of the R. T. Vanderbilt Company, is ground kaolin of 300 mesh, used as a stiffening or reinforcing agent in rubber and adhesives. Finely ground powder for cosmetics and pastes is marketed under many trade names such as Osmo of E. Fougera & Company. Aluminum flake, of the Aluminum Flake Company, is a kaolinic clay from Missouri. It is in the form of white, flakelike chips, and is used as a filler in paints, adhesives, and rubber.

**Kapok.** A silky fiber obtained from the silk-cotton tree, *Ceiba pentandra*, common in most tropical countries. It is employed for insulation and fine padding work. It is extremely light and resilient. Most of the commercial kapok comes from Java. The tree is very large, and the fiber grows in bolls, which burst when ripe. The fibers are long, white, and silky, similar in appearance to cotton, but are too brittle for spinning.

**Kauri gum.** A fossil gum dug from the ground in New Zealand, used in varnishes, lacquers, and enamels to increase the body, and also in adhesives. It is a product of kauri tree exudations buried for long periods, but kauri also comes from the conifer tree *Agathis australis*. There is little extraction of the gum from the present kauri forests, whose wood is employed for lumber, but some Bush gum is obtained by collecting the deposits in the forks of branches. Range gum is found in clay

deposits, and some is transparent. Swamp gum is brown in color and varies from hard to friable. The fossil gum has a specific gravity of 1.05, a melting point of 182 to 232°C., and is soluble in turpentine, benzol, and alcohol. Kauri gives elasticity and good wearing qualities to lacquers. The lower grades of chips are used in linoleum.

**Keene's cement.** Also known as Flooring plaster, or Tiling plaster. A white powder which with water makes a superior kind of plaster that will set very hard and white. It is used in the United States to imitate tiling and in Germany for flooring. Keene's cement is made by burning gypsum at about 110°C. to plaster of paris, dipping the burned lumps in a solution of alum, drying, and then burning again at from 400 to 500°C. The product is then ground to powder. Heating at higher temperatures, or prolonged heating, ruins the cement by causing it to lose its power of setting. Parian cement is similar to Keene's cement, except that borax is used instead of alum. Martin's cement is made with potassium carbonate instead of alum. These cements are also called Hard finish plaster.

**Kermes.** A brilliant red natural dyestuff similar in color to cochineal, having a beautiful tone and being very fast. It is one of the most ancient dyes, but is now largely replaced by synthetic dyestuffs. Kermes is an insect found on the kermes oak tree, *Quercus coccifera*, of southern Europe and Asia. The body of the animal is full of a red juice, and the coloring matter, Kermesic acid, $C_{18}H_{12}O_9$, is separated out in brick-red crystals. It has only about one-tenth the coloring power of cochineal.

**Kermesite.** An ore of the metal antimony, and also known as Red antimony. It results from the partial oxidation of the mineral stibnite. The composition is $Sb_2S_2O$; when pure it contains 75 per cent of antimony and 20 of sulphur. It occurs in hairlike tufts, or radiating fibers of a cherry-red color and metallic luster. It has a hardness of 1 to 1.5, and a specific gravity of 4.5. The mineral is found in deposits in Italy.

**Kerosene.** Known also in some localities as Coal oil. A light, oily liquid obtained in the fractional distillation of

petroleum oils. It distills off after the gasoline, and between the limits of temperatures of 174 and 288°C. It is a hydrocarbon of the composition $C_{10}H_{22}$ to $C_{16}H_{34}$, with a specific gravity between 0.747 and 0.775. Commercial kerosene may be as high a distillate as 325°C., with a corresponding higher specific gravity up to 0.850. Kerosene is employed for illuminating and heating purposes, and as a fuel in internal-combustion engines. The heaviest distillate known as Range oil is sufficiently volatile to burn freely in the wick of a heating range, but not so volatile as to be explosive, and is nearly free from odor and smoke.

**Kid.** A name for leather made from the skins of young goats, but commercial Kidskin leather is now from both young and old animals. It is thin and has a fine, close-grained texture, with tiny groups of pores, and the leather is soft and pliable. Kid is usually chrome tanned and dyed to many colors. The leather is sorted by grain, weights, and sizes into 10 grades. It is used for shoes, gloves, pocketbooks, jerkins, and for pads and linings. The term Vici kid, used in the shoe industry, was the name originally given to chrome-tanned leather in 1888. The best kidskins come from arid regions, and these are used for the fine French kid leather. In the glove trade the term Chevreau is used to designate young goats that have never browsed, while Chevrette refers to the small skins of older kids that have eaten grass. Capeskin is goatskin from South Africa. Glazed kid is made by pressing a seasoning agent into the pores of the leather and then ironing the dry leather with a glass cylinder.

**Kieselguhr.** A variety of tripoli, or Infusorial earth, obtained in Germany, and employed chiefly as an absorbing material. It is also used as an abrasive, as a heat insulator, for making imitation meerschaum, and as an absorbing material for nitroglycerin in making dynamite. Kieselguhr is very absorbent and will hold 75 per cent of its own weight of sulphuric acid. It is insoluble in water. Desirable characteristics as an insulator are closed cells and high porosity, giving low density and low thermal conductivity. Kieselguhr from Oberhole, Germany, has 88 per cent silica, 0.1 alumina, 8.4 water, and the remainder organic matter.

Nonpareil insulating brick, of the Armstrong Cork & Insulating Company, is made of pulverized kieselguhr mixed with ground cork, molded into brick form and dried. The cork is burned out, leaving small air pockets to increase the insulating effect. The bricks will withstand temperatures up to 1000°C.; the heat transmission is lower than for natural kieselguhr.

**Kino resin.** Also known as Gum kino. The red exudation of the tree *Pterocarpus marsupium*, of India and Ceylon, and of *P. erinaceus*, of West Africa, formerly much used for colored varnishes and lacquers. Bengal kino, or Butea gum, from the tree *Butea frondosa*, is now limited to medicinal use, as is also the Australian red kino from species of eucalyptus. Kino belongs to the group of red resins known as Dragon's blood when used in spirit varnishes for musical instruments and furniture, but now replaced by synthetic colors. The dragon's blood resins from the East Indies are from various species of the tree *Daemonorops*. The resin is separated out by boiling and is shipped in cakes.

**Kittool.** A fine fiber obtained from the large leaves of the palm tree *Caryota urens*, of Ceylon and India. It is stiff, elastic, and strong, and is employed for brushes. Another species of palm, *Arenga saccharifera*, yields the Arenga fiber, which is practically the same thing. The finest grades of arenga fiber resemble horsehair. Other names are used to designate brush fibers from this class of palm, such as Chinese coir, Philippine cabo negro, and Gommuti fiber. Kittool is especially valued for machine brushes because of its elastic strength and resistance to water.

**Kunheim metal.** A pyrophoric, or sparking, alloy used for cigarette lighters. It was covered by French patent in 1909, and consists of hydrides of the cerium mixed metal. It is produced by melting the misch metal with magnesium and aluminum, and then heating the alloy thus made in a current of hydrogen at a temperature of about 500°C. The metal contains 36 per cent of cerium, 49 per cent of lanthanum and didymium, 10 per cent of magnesium, and 1 per cent of aluminum. See Misch metal.

**Lace leather.** Originally leather made from the skins of porpoises, or dolphins, and used in making laces for machinery

belting. The fish skins were tanned with alum and salt and permitted to dry hard. They were then moistened with water and oiled with cod oil. The leather is very tough, pliable, and strong. It is now made with alum-tanned and oil-treated cow hide or calfskin. Helvetia leather, for belt laces and light belts, is weak-tanned with gambier or spent oak liquor and then oil tanned with grease and salt.

**Lacquer.** Originally the name for a kind of Oriental finish made with certain slow-drying varnishes, but now referring to the quick-drying finishes made from nitrocellulose, or pyroxylin, or from cellulose acetate resins. The original Chinese lacquer was made from the juice of the *Rhus vernicifera* mixed in oils. The juice is milky but darkens rapidly, and the lacquer is pure black.

Modern lacquers are widely used for finishing automobiles and other articles. They consist of pyroxylin or other resin, one or more gums, a pigment, a softener, and one or more volatile solvents. Various kinds of gums are used for increasing the body and giving hardness and gloss to the finished surface. For high gloss and hardness, dammar is used. For a cheaper product elemi may be employed. Kauri is used where good wearing is required. The usual solvents are anhydrous alcohol, ethyl acetate, butyl acetate, butenol, benzol, and toluol. Softeners are such products as amyl, ethyl, and butyl phthalates. Quick drying is the chief advantage of the lacquers, but the time must be made long enough to prevent cloudiness, or "blushing," from absorption of moisture from cooling by too rapid drying. For industrial work lacquers are usually sprayed, and they then dry in about 15 min. Brushing lacquers are made slower in drying to prevent streaks and lumps in their application. The time of drying is controlled by the solvents.

Lacquers are harder and tougher than enamels, but not as elastic, and are more expensive. They are not suitable for exterior woodwork where expansion and contraction occur. The word lacquer is also used to describe a highly transparent varnish used to produce a thin protective film on polished or plated metals to preserve their luster. Synthetic-resin lacquers, such as colorless

Bakelite lacquer, are used for protecting the finish of builders' hardware. Lacquers are sold under a variety of trade names such as Duco, of E. I. du Pont de Nemours & Company, Inc.; Agateen, of the Agate Lacquer Manufacturing Company; Zapon, of the Zapon Company; Zelactite, of the Zeller Lacquer Manufacturing Company; and Brevolite, of the Brevolite Lacquer Company. See Nitrocellulose, Pyroxylin, Cellulose acetate.

**Lampblack.** A soot formed by the smudge process of burning oil, coal tar, resin, or other carbonaceous substances in an insufficient supply of air, the soot being allowed to settle on the walls or floors of the collecting chambers. Lampblack is practically pure carbon, but inferior grades may contain unburnt oil. It is chemically the same as carbon black made from gas but, since it may contain as high as 2.5 per cent of oil, it is not used as a reinforcing agent in rubber. It is used in making paints, lead pencils, metal polishes, electric brush carbons, crayons, and carbon papers. It is grayish black in color, and is flaky and granular. The color is not as intensely black as carbon black. One pound occupies from 200 to 230 cu. in. For use as a pigment for japan the powder should pass through a 325-mesh screen. Lampblack oil is a coal-tar product marketed for making lampblack. See also Carbon black.

**Lancewood.** The wood of the tree *Guatteria virgata*, of tropical America. It is used for fine work where toughness, uniformity, and durability are requisites, such as for measuring rods. It is used also as a substitute for boxwood. The wood is yellowish in color and has a fine, close, smooth grain. The weight is 52 to 63 lb. per cu. ft. It is very hard and elastic. Yaya is a name given in the Honduras trade to lancewood. Degami lancewood, or Degami wood, is a yellowish wood with a fine, dense grain, from the tree *Calycophyllum candidissimum*, of the West Indies.

**Lanthanum.** A metallic element, symbol La. It is a white metal, malleable and ductile, with specific gravity of 6.154 and melting point of 810°C. It is easily soluble in acids and oxidizes readily in the air. Practically the only use for lanthanum is in the form of Lanthanum oxide, $La_2O_3$, a white powder used for gas

mantles, and in misch metal for absorbing gas in vacuum tubes. It is produced by electrolysis.

**Larch.** The wood of the coniferous tree *Larix occidentalis*, Western larch, of northwestern United States and southwestern Canada. The wood is strong, moderately hard and heavy, straight-grained, and of medium durability. It is used for railroad ties, car building, and general construction. The stand is estimated at 23 billion bd. ft., of which half is in Montana. The trees reach a diameter of 5 ft., and a height up to 200 ft. at an age of about 400 yrs. Shipments of Western larch and Douglas fir mixed are known commercially as Larch-fir. Larch is also the name given to the Tamarack tree of New England, *L. laricina*. European larch, *L. europea*, is an important wood in Russia and some other European countries.

**Lard oil.** An oil obtained by subjecting lard or grease to hydraulic pressure. See Grease. Prime or first-grade lard oils are nearly colorless, or greenish, and have little odor. The commercial oils vary from the clear sweet oil to the acid and offensive-smelling brown oils. The oils contain oleic, stearic, and palmitic acids. They are used in cutting and in lubricating oils, sometimes in illuminating oils. They may be adulterated with cottonseed oil or blown oils. The flash point of pure lard oil is 480°F., saponification value 192, and specific gravity 0.915. Mineral lard oil is a mixture of refined mineral oil with lard oil, the fatty content being 25 to 30 per cent. The flash point is about 300°F.

**Latex.** The milklike juice of the rubber tree, now much used instead of the cured crude rubber for many rubber applications such as adhesives, rubber compounds, and rubber powder. The properties of latex vary with the type of tree, age of the trees, method of tapping, and climate. Latex from young trees is less stable than from older trees. Intensive tapping of the trees results in less rubber content, which may vary from 20 to 50 per cent. For shipping, a preservative and anticoagulant is added to the latex, usually ammonia or sodium sulphate. Concentrated 60 per cent latex is a stable liquid of creamlike consistency.

Heveatex is the trade name of latex of various grades of the Heveatex Corporation. Latex foam is a name given to a type of cellular sponge rubber made by whipping air into latex, pouring into molds, and vulcanizing. Artificial latex is a water dispersion of reclaimed rubber. Dispersite is a trade name of Dispersions Process, Inc., for water dispersions of crude or reclaimed rubbers, produced by swelling and dissolving the rubber in an organic solvent, treating with an organic acid or with ammonia, and emulsifying. It resembles latex, but is softer and more tacky, and is used for adhesives. Lotol and Revertex are brands of latex.

**Lava.** A name given to ceramic material used for molding gas-burner tips, electrical insulating parts, nozzles, and handles. It may be talc, steatite, or other material. As produced by the American Lava Corporation, it is molded from magnesium oxide, and it is hardened by heat-treatment after shaping and cutting. It is baked at 2000°F. The compressive strength is from 20,000 to 30,000 lb. per sq. in. It will resist moisture and has high dielectric strength. Rods as small as 0.020 in. in diameter can be made. Alsimag is the trade name of a lava produced by this company from ground talc. Porcelava is a similar ceramic produced by Burgess and Company, for electric insulators and for the refractory parts of electric heating appliances. Isolantite, of the Isolantite Company of America, Inc., is a steatite ceramic molded with a binder and then vitrified. It can be machined or threaded before firing and, by allowing for the contraction, parts can be made with great accuracy. The specific gravity of the vitrified material is 2.5, hardness 8 to 9 Moh, crushing strength 80,000 to 120,000 lb. per sq. in., and the dielectric strength of a ⅛ in. thickness 40,500 volts. Lavalloy, of the Lava Crucible Company, is a high-strength ceramic made from a mixture of mullite and aluminum oxide.

**Lead.** A soft, heavy, bluish-gray metal with a granular structure, and a strong metallic luster. Its chemical symbol is Pb. Lead is obtained chiefly from the mineral galena. It surface-oxidizes easily, but is then very resistant to corrosion. It is soluble in nitric acid but not in hydrochloric or sulphuric, and is one of the most stable of metals. However, it becomes hard

and brittle on repeated melting due to the formation of oxides. Lead is believed to be the ultimate substance produced by the disintegration of uranium and radium. Its specific gravity is 11.38, melting point 621°F., and boiling point 2787°F. The tensile strength is low, about 3,000 lb. per sq. in., but it is very malleable. The coefficient of thermal expansion is 0.0000183. Lead is used for pipes and cable coverings. It alloys easily with tin and other metals, and forms many commercial alloys, including solders and babbitts. It is also used for lining acid tanks, and for storage battery plates. Its compounds are used in paints, especially white lead. About 30 per cent of all lead is used for storage batteries, 20 per cent for pigments, and 10 per cent for cable coverings.

Commercial lead is sold in pigs weighing 100 lb. Four grades of lead are marketed: Corroding lead, 99.93 to 99.99 per cent pure, for making white lead; Chemical lead, with some silver and copper, for storage batteries, and coverings; common Desilverized lead; and soft Missouri lead. Work lead is the pig lead from the blast furnaces before the silver is extracted. Lead and its compounds are highly poisonous. Lead for Lead pencils is amorphous graphite, or graphite mixed with clays, while Indelible lead for the same purpose may be graphite with a coal-tar dye. See also Bismuth amalgam. Alkali lead is lead hardened by small additions of the alkali metals. See Bahnmetall. Hard lead is antimonial lead used for sulphuric acid tanks and pipes. It contains 16 per cent of antimony, and is called in England Regulus metal. Lead wool is lead in a shredded form used for caulking joints of water pipes. The strands are 0.005 to 0.015 in. in diameter, and come in ropes, ⅝ to ¾ in. in diameter.

Blue lead is a term meaning all lead products such as pipe and shot that have not been changed chemically in manufacture. Blue lead is also a name for Basic lead sulphate, a by-product of the smelting of lead ores obtained by collecting and filtering the smoke from the furnace. It is a mixture of the products of the partial combustion of the ore and coal. It consists of lead sulphate, lead sulphide, lead sulphite, lead oxide, zinc oxide, and carbon. It is used in base-coat paints for steel. Cable lead was

originally lead with 2 to 3 per cent of tin used for protecting wire, but antimony is now substituted for the tin. Lead-coated copper, used for roofing and for acid-resistant tanks, is 16-oz. copper sheet, coated on both sides with lead, made with either a rough or smooth finish. Leadtex, of Revere Brass and Copper Company, is a lead-coated sheet copper. Tea lead, used for wrapping tea, is lead with 2 per cent of tin. Shot lead is lead hardened with a small quantity of arsenic. Amaloy is a tin-lead alloy of the American Machine and Foundry Company, used for hot-dipping iron and steel parts to give a corrosion-resistant coating. It contains up to 1 per cent of tin, and is applied by a patented process.

**Lead chromate.** A paint pigment generally known as Chrome yellow, and also called Leipzig yellow. It has the composition $PbCrO_4$, and comes in yellow, poisonous crystals. The specific gravity is 6.123. It is insoluble in water and decomposes at 600°C. Basic lead chromate, $2PbO \cdot CrO_3$, is red in color and is used for anticorrosive base coats for steel. American vermilion, also called Chinese scarlet and Chrome red, is basic lead chromate made from white lead.

**Leaded high brass.** An alloy containing approximately 65 per cent of copper, from ½ to 1½ per cent of lead, and the remainder zinc. It is one of the standard grades of brass, and is also called Free-cutting brass. It is easier to machine than high brass but is less ductile. It is used especially for cupped, drawn, or formed parts on which a clean thread must be cut. The property of free cutting is gained at the expense of its drawing capacity, but the material is mostly employed in the form of rods for screw machine work or in sheets for blanking. See Clock brass. The free-cutting brass rod of the Bridgeport Brass Company contains 61.5 per cent of copper, 35.5 zinc, and 3 lead. All impurities, including iron, are below 0.25 per cent, since as little as 0.50 per cent of iron will harden brass 20 points Rockwell. The free-cutting brass of the Chase Brass and Copper Company has the same amount of copper, but has 3.5 per cent of lead. A brass of this class will have a tensile strength of 57,000 lb. per sq. in., elongation of 25 per cent, and Brinell hardness up to 110.

Ledrite brass is the name of the Bridgeport Brass Company for leaded brass containing 60 to 63 per cent of copper and 2.5 to 3.75 of lead. The alloy known as Architectural bronze, used for extruded moldings and for forgings, contains 57 per cent of copper, 40 zinc, 0.25 tin, and 2.75 lead. The free-machining alloy known as Arsenical bronze is a leaded high brass modified with other elements. A typical analysis is copper, 56.5 per cent; zinc, 39; lead, 0.70; nickel, 2; iron, 1.20; and arsenic, 0.60. The tensile strength is 65,000 to 87,000 lb. per sq. in., elongation 11 to 40 per cent. It is wear resistant and corrosion resistant.

**Leaded steel.** A free-machining steel containing about 0.25 per cent of lead. Lead does not alloy with iron but is distributed in finely divided particles and strings. It gives free machining without imparting to the steel the unfavorable characteristics given by sulphur or phosphorus. The lead is in such a fine state of dispersion that it cannot be detected except with the most powerful microscope, and there is no weakening effect on the physical properties of the steel. Ledloy, of the Inland Steel Company, contains 0.15 to 0.30 per cent of lead in the regular S.A.E. grades of steel.

**Lead foil.** Very thin sheet lead, or soft lead alloys, used for wrapping tobacco and other nonedible products. It is made in thicknesses from 0.006 mm. (0.00024 in.) to 0.200 mm. (0.00787 in.), the former having 10,358 sq. in. per lb., and the latter 279 sq. in. per pound.

**Lead ores.** The chief ore of the metal lead is Galena, a lead sulphide, PbS, containing theoretically 86.6 per cent of lead. The ore, however, contains many other minerals and usually carries only 4 to 11 per cent of lead. It is concentrated by wet gravity methods to contain 40 to 80 per cent of lead. Galena has a bright metallic luster, streaked gray, a specific gravity of about 7.5, and hardness of 2.75. It frequently contains silver and sometimes cadmium, bismuth, and copper. The lead is obtained from the concentrated ore by roasting to remove the sulphur, and smelting. The ingot lead from the blast furnaces contains silver,

copper, zinc, and other impurities. It is refined and desilverized. Southern Missouri is the chief source of galena lead production in the United States.

The abundant lead ores Cerussite and Anglesite are secondary minerals formed by the oxidation of galena. Cerussite is a lead carbonate, $PbCO_3$, found in crystals or in granular crystalline aggregate or massive. Its color is white to gray, transparent to opaque. The hardness is 3 to 3.5 and the specific gravity 6.55. Anglesite is found usually in the oxidized portions of lead veins associated with galena and other minerals. It is a common mineral occurring in many localities. Anglesite is a lead sulphate of the composition $PbSO_4$, containing 68 per cent of lead. It occurs in crystals, massive, or granular. Its hardness is 2.75 and specific gravity 6.12 to 6.39. The color may be white or pale shades of yellow or blue, or it may be colorless.

**Lead pigments.** Chemical compounds of lead used in paints to give color. They are to be distinguished from the lead compounds such as lead oleate, used as driers for paints. White lead, $2PbCO_3 \cdot Pb(HO)_2$, is the most common, and is made from $PbSO_4$ or $PbCl_2$. It is frequently mixed with barium sulphate, barium carbonate, chalk, or clay. Chrome yellow is lead chromate, $PbCrO_4$. Orange mineral is the red oxide, $Pb_3O_4$. Madder reds, vermilionettes, and Brunswick greens are also pigments of lead. Mixtures of white lead and heavy-spar are known as Venetian white. Dutch white is composed of three parts of sulphate and one part of carbonate. All the lead compounds are poisonous by skin absorption or when taken internally. See White lead, Red lead, Litharge, Lead chromate. Lead thiosulphate, $PbS_2O_3$, is a white insoluble powder, used chiefly in matches.

**Leather.** The skins or hides of animals, cured by the chemical action of tannins. Leather is used for belting, gaskets, and for a variety of other purposes. The action of tannins precipitates the protein of the hide, changes its colloidal structure, and makes it more pliable and capable of resisting decay. The process of tanning hides consists essentially in soaking them in solutions of the tanning material after they have been unhaired in caustic lime. See Tannins, Bates, and Fat liquors. This soaking

may be prolonged for several months, after which the hides are washed, oiled, and rolled. Cheap leathers are tanned quickly with strong solutions of tannin, but rapid action does not produce the desired chemical changes. The quality of leather depends upon the type of animal, its physical condition, the care used in taking off the hide, the method of preserving the hide before tanning, and the care used in tanning. Leather is used for a great variety of purposes, and is made from many kinds of skins, including sheep, goat, deer, alligator, seal, and shark, although the bulk of commercial leather is made from cattle hides. Animals raised in the open have hides that produce tough, close-grained leather; breeded cattle raised for meat produce the weakest leather. But in general, packing-house hides, well skinned, and packed in brine make the best leather if properly tanned.

Belting leather is usually made from salted hides free from cuts and scratches, and is either oak or chrome tanned. It is then "stuffed" with oils or tallows. Belting leather weighs about 0.035 lb. per cu. in. and has an ultimate strength of about 3,800 lb. per sq. in. Belting is now sold by the thickness instead of the weight because of the old practice of weighting the leather by the addition of heavy impregnations. Leather was once used widely for packings and gaskets but has now been largely replaced by special compounded materials. Where it is used for this purpose, oak-tanned or chrome-tanned is preferred. The Wax calf leather, once popular for men's shoe uppers, was a leather heavily stuffed with oil, grease, and wax. It sheds water and is wear resistant, but oily leathers are no longer desired in shoes. Cordovan is a tough, smooth, close-grained leather made from the hind quarters of horsehides. It takes a beautiful polish and is used for fancy articles. Another fancy leather is Ostrich leather used for handbags. The skin is marked with tiny rosettes where the quills are extracted. It is imitated in embossed calf. See also Lace leather, Kid, Upholstery leather.

**Leather board.** Also called Imitation leather, or Fiber leather. A solid paper-type of board made from pulped scrap leather sometimes mixed with jute, wood pulp, or kraft paper

to harden and stiffen it. It is used for making trunks and cases. Artificial leather, used for making washers, gaskets, and clutch linings, is made from pulped leather scrap compressed with a binder. Leather board for built-up shoe heels is made with or without a binder. It is sometimes sold under trade names such as Herkolite of the Herkimer Fiber Company. Reletha, of the Prospect Mills, Inc., is a leather substitute for shoe linings made of scrap leather fibers.

**Leather dust.** The light, fluffy material blown from the buffing and suèding wheels in tanneries. It has a limited use as a covering material for Artificial suède or Suèded fabrics. In Europe it is more extensively collected, and is also used as a filler in caulking compounds. It is very light, giving 20 bbl. to the ton. Its disadvantage for commercial use is its lack of uniformity, being the refuse from many varieties of leather with different tannages and colors not kept separate in American tanneries.

**Leather fabric.** A substitute for upholstery leather made by applying a pyroxylin or other coating to a cotton fabric. The foundation cloth may be of various weights and may be firm or napped on the back. It ranges from light-coated sheetings to heavy-coated sateens, ducks, and moleskins, and is marketed in many colors or embossed with designs. It is waterproof, is more durable than ordinary split leathers, and is cheaper. Fabricoid, of the E. I. du Pont de Nemours & Company, Inc., is marketed in many weights, colors, and designs, and is used also for automobile tops, book covers, and waterproof bags. Tontine, of the same company, is a pyroxylin-impregnated cloth used for window shades. Pontan, of this company, is a rubberized fabric made to imitate colored leathers.

**Lepidolite.** A lithia mica occurring usually in small plates, with muscovite, or common mica. The composition is $KLi(Al\cdot 2OHF)Al(SiO_3)_3$. It is the chief ore of the metal lithium and also carries more rubidium than any other known mineral, containing from a trace to 3 per cent of Rubidium oxide, $Rb_2O$. It may also have caesium oxide. The hardness is 2.5 to 4, and specific gravity 2.8. It has a pearly luster, and color pink and lilac to grayish

white. It is insoluble in acids. Lepidolite is employed as a source of lithium compounds, and of the metals rubidium and caesium. It is also used in making opal and white glasses. Glassmakers' lepidolite contains 4 per cent of $Li_2O$; West African lepidolite usually contains 3.75 per cent.

**Lethal gases.** Poisonous compounds used in chemical warfare, and having deadly effects, as distinct from gases used for disabling. Lethal gases are divided into four classes: actual poisons, which kill with little pain, such as hydrocyanic acid; asphyxiating poisons, which affect the membranes of the lungs, destroying them and allowing blood to fill the air sacs, such as phosgene, diphosgene, and chloropicrin; poisons which destroy the lining of the air passages and block the passages to the lung tissues, as mustard gas and ethyl-dichloro-arsine; and poisons which affect the nose and throat, causing great pain, headache, vomiting, pressure on the chest, sneezing, unconsciousness, and weakness, such as diphenyl-chloro-arsine. The effects of these gases are usually in proportion to the concentration and duration of exposure. A person exposed for 2 min. in a given concentration of phosgene would suffer the same as a person exposed for 1 min. in a concentration twice as great. The only protection against lethal gases is by covering the breathing system with masks containing activated charcoal, soda lime, or chemical absorbents, although some sneezing gases will enter these and force their removal. See also Poison gases, Lewisite, Mustard gas, Phosgene, Diphosgene, Diphenyl-cyanoarsine.

**Lewisite.** A highly toxic vesicant and lethal poison used in chemical warfare. It is an almost colorless liquid of the composition $ChCl{:}Ch{\cdot}AsCl_2$, having a boiling point of 190°C. and specific gravity of 1.885. Lewisite was popularly known as Dew of Death. Its chemical name is Chloro-vinyl-dichloro-arsine. It is made by the action of arsenic trichloride on acetylene in the presence of aluminum chloride. A secondary and a tertiary compound are formed at the same time, but the mixed product is employed in the crude state because of the danger of exploding on distillation. Lewisite is the strongest vesicant known and forms painful blisters on the skin; its effect also passes into the system,

causing arsenic poisoning. It also attacks the throat, nose, and lungs. It is thrown in high-explosive shells and disseminated as a persistent mist.

**Licorice.** The sweet roots of a group of plants of the order *fabraceae.* The common licorice of Spain is *Glycyrrhiza glabra,* and of Italy, *G. echinata.* Certain other species, all native to southern Europe, are also employed. Licorice is employed in confectionery, in medicines, and in beverages, but industrially it is used for fire extinguishers to produce a froth to smother the fire. The dark-colored extracted juice of the roots contains a glucoside, which will not ferment. Licorice also contains a Saponin, or froth-producing substance. In fire extinguishers it is sold under trade names. An insulating building board made from the fibers of the roots of the licorice plant is produced by the National Gypsum Company. The fibers make a tough and strong board resistant to the attacks of insects.

**Lignite.** Also called Brown coal. A variety of coal of more recent age than coal, occurring in rocks of tertiary age, and intermediate in composition between wood and coal. It is widely distributed over Europe. Freshly cut lignite often contains a large quantity of water, up to 40 per cent, and is sometimes also high in ash. When dried it breaks up into fine lumps and powder. Dry lignite contains 55 to 75 per cent of carbon, 10 to 30 per cent of oxygen, and 5 to 7 per cent of hydrogen. It kindles easily but burns with a low calorific power and a smoky flame. In retort gas production lignite loses its gas in half the time required for gas removal from bituminous coal, with a temperature of 1270°F., compared with 1655°F. for bituminous. The color of lignite varies from brown to black, and the lower grades of brown lignite show the woody structure. The Pitch coal is brownish black, breaks with a pitchlike fracture, and shows no woody structure. Lignite is briquetted by crushing and pressing with a binder under heat. Belgian lignite briquettes have a binder of 8 per cent of asphalt, with 2 per cent of flour to assist binding. The reserves of lignite in the United States are estimated at a thousand billion tons, and form a future fuel for use in powdered form, or for distillation of oils and coal-tar products.

**Lignum vitae.** The wood of the guayacum trees, *Guaiacum officinale*, and *G. sanctum*, of tropical America, but the commercial shipments of lignum vitae are likely to contain also other species. The wood of the Guayacan tree of Brazil and Paraguay is also called by this name. The best quality of the true lignum vitae comes in logs up to 18 ft. long and 12 in. in diameter. It is very hard, heavy, and tough. The color is brown to greenish black. The grain is very fine and even. The weight is from 72 to 88 lb. per cu. ft., and the crushing strength is 10,000 lb. per sq. in. The wood is used in places where extreme hardness is needed, such as for pulley blocks. It is also used for rollers, handles, novelties, bearings, and furniture. In machine bearings it withstands pressures up to 4,000 lb. per sq. in. Guaiac gum, also called Guaiacum, is the gum resin of the lignum vitae trees used in varnishes, although its chief use is in medicine. The resin has a greenish-brown color.

**Lime.** A calcium oxide, $CaO$, occurring abundantly in nature, chiefly in combination with carbon dioxide as calcium carbonate, in limestone, marble, chalk, coral, and shells. As calcium phosphate it occurs in combination in bones and in some minerals. It is employed in mortars, cements, as a flux in steel making, a lubricant in wire drawing, and in many purifying processes, especially gas absorption. In the various mineral forms it is used for a flux in melting iron and for building stones. Lime is obtained by heating limestone in a furnace, or kiln, to burn out the carbonic acid gas. The residue is called Quicklime or Caustic lime. Pure quicklime is white and amorphous or crystalline. The specific gravity is 3.2 and melting point 4660°F.

Commercial limes contain about 94 per cent of calcium oxide, some calcium carbonate, and less than 0.50 per cent of magnesia. Water causes the lime to slake with much heat, leaving a white powder, $CaOH_2O$. High calcium limes slake rapidly and expand greatly on slaking and are the strongest. Limes with much magnesia slake slowly, but magnesia produces the slip that makes easier working. The so-called lean limes contain considerable silica, alumina, and iron oxide, and are slow slaking and difficult to work. Lime is marketed in lumps or ground to 20

mesh, and as "mill run." Hydrated lime is made by grinding quicklime, slaking the powder with water, and sifting to a fine powder. It is easier to handle and is a more reliable product than ordinary lime. High-grade hydrated lime will have a fineness so that 98 per cent will pass through a 100-mesh sieve and will contain not over 2 per cent of magnesia. Some grades contain less than 0.50 per cent of magnesia, and 98 per cent pass through a 200-mesh sieve. Lime is usually marketed in barrels of about 200 lb. each; hydrated lime comes in 100-lb. burlap sacks or 40-lb. paper bags. Lime mortar, made of a mixture of hydrated lime, sand, and water, will have a compressive strength of 150 to 400 lb. per sq. in. See also Hydraulic lime.

**Limestone.** A term applied to a great variety of rocks which contain lime. Immense quantities of limestone are used as flux in the melting of iron. See Fluxing stone. Limestone is used widely as a building material; for this purpose it is preferred in granular compact masses well bonded to form a hard, uniform stone. Limestone has the composition $CaCO_3$, and on calcination in a furnace yields lime, CaO. In its broad sense limestone includes marble, chalk, dolomite. Many limestones contain considerable magnesium carbonate $MgCO_3$. See Dolomite. The Portland stone of England consists of fossils cemented together with lime. Indiana limestone, used for building, is a noncrystalline rock, with aggregate, filler, and matrix all of pure carbonate of lime. The colors are shades of gray and buff. The average weight is 144 lb. per cu. ft., and the crushing strength is 6,000 to 8,000 lb. per sq. in. The "mill blocks" range from 8 to 12 ft. in length and are 3 ft. 6 in., or 4 ft. 4 in. square. See also Marble.

**Limonite.** Also called Brown hematite, Brown ore, or Bog-iron ore. A common ore of iron of secondary origin formed by the water solution of other iron minerals. Its composition is $2Fe_2O_3 \cdot 3H_2O$, containing theoretically 59.8 per cent of iron, but usually 30 to 55 per cent. It occurs earthy or in stalactitic forms of a dark-brown color. The specific gravity is 3.6 to 4. Limonite is found in Alabama, Tennessee, and Virginia, and is also an English and German ore. Some varieties are used as a pigment, as Yellow ochre and Brown ochre. Goethite is a minor ore of iron of the

composition $Fe_2O_3 \cdot H_2O$, found in the Lake Superior hematite deposits and in England. It is yellowish brown in color with a specific gravity of 4.3. It is also called Turgite. When limonite is in the form of loose rounded particles, it is called Shot ore. See Iron ores.

**Linen.** A general name for the yarns spun from the fiber of the flax plant, or for the cloth woven from the yarn. Linen yarns and fabrics have been made from the earliest times, and the ancient Egyptian linen fabrics were of exceeding fineness. Ireland, Belgium, and France are the principal producers of linen. Linen yarns are used for the best grades of cordage, and linen fabrics are employed industrially wherever a fine, even, and strong cloth is required. Linen fabrics are sold under a wide variety of trade names. They are graded chiefly according to the fineness of the yarns and the class of weave. Lisle was formerly a fine, hard linen thread, made at Lille, France, but is now a fine, smooth yarn made of long-staple cotton spun tightly in a moist condition. Tow yarns are the coarsest linen yarns, used for making Crash, a coarse towel fabric (see also Cotton).

**Linoleum.** A general trade name for a floor-covering material consisting of a fabric impregnated and covered with a compound of blown linseed oil, ground cork or wood flour, and rosin or other gum. It is rolled under great pressure, and then dyed in plain colors or printed with designs. In good quality linoleum the cork is ground to a 50-mesh screen, and the pressed material will take printing or coloring evenly. A filler of lithopone or other material may be used. The fabric may be of jute or other coarse material. Linoleum was invented and patented in 1863 and displaced the older Kamptulicon floor covering, which was made of rubber, cork, rosin, and boiled oil, and was more expensive. Battleship linoleum is very heavy linoleum in plain colors or mosaics.

**Linseed oil.** This oil is the most common of the drying oils, and is widely used for paints and varnishes. It is obtained by pressure from the seeds of the flax plant, *Linum usitatissimum*, which is cultivated for oil purposes in Russia, India, North and

South America. Argentina is the greatest producer of linseed. The seed contains up to 40 per cent of oil. The commercial oil is hot pressed and has a bitter taste; in Russia a cold-pressed oil is used for food purposes. Linseed oil contains about 48 per cent of linoleic and 34 per cent of linolenic acids. The specific gravity is 0.925 to 0.935. It is a yellowish oily liquid with a peculiar odor and a bland taste. It is soluble in turpentine, ether, and benzine. It dries with a distinct gloss and makes a hard film. The best Baltic oil is used as a standard in measuring the drying power of other oils. Genuine linseed oil has an iodine value of at least 170, and the best approach 190. The oil is sometimes adulterated with rosin oil. For varnish use it is bleached by heating and forcing oxygen through it, or used as Boiled linseed oil, prepared by boiling in a kettle or by heating with oxidizing driers such as the salts of lead or manganese. When prepared with driers it is called Bung oil. Stand oil, also known as Lithographic oil, is linseed oil heated for several hours without blowing, at a temperature of 550 to 650°F. It has the consistence of honey and is used in oil enamel paints. Blown oils and boiled oils are not greasy like the original oil. Linoxyn is a trade name for blown linseed oil. The purity and adulteration of linseed oil for paint and varnish use are controlled by state laws. The law of the state of Ohio, which is typical, defines Boiled linseed oil as prepared from pure raw linseed oil heated to a temperature of 225°F., and incorporating not to exceed 4 per cent by weight of drier, and with specific gravity at 60°F. of not less than 0.935 and not greater than 0.945.

**Linters.** The short cotton fibers that adhere to the seed after ginning. Linters removed from the cotton seed are ⅛ in. long or shorter, gray and brown in color, and are used as a filling and padding material, and also as the raw cellulose material for the manufacture of artificial silk, smokeless powder, and pyroxylin plastics.

**Liquid air.** Atmospheric air liquefied under great pressure. The boiling point is about −310°F., and it is used in the mechanical industries for cold-treating metals to be shrunk into place. It is marketed in vacuum bottles, and as the ordinary evaporation is 4 to 8 per cent a day, it is shipped only just prior

to use. Liquid air is also used as a source of oxygen, since it contains more than 20 per cent of free oxygen. One cu. ft. of liquid air makes 792 cu. ft. of free air. See also Lox.

**Litharge.** The yellow Lead monoxide, PbO, also called Massicot. It is a yellow powder used as a pigment and also in the manufacture of glass, and for fluxing and glazing of earthenware. An important use is as a filler in rubber. With glycerin litharge is used as a plumbers' cement. The specific gravity is 9.375. Litharge is produced by heating lead in a reverberatory furnace and then grinding the lumps. For storage battery use the black oxide, or suboxide of lead, is now substituted, although much litharge is employed.

**Lithium.** The lightest of all metals, with an atomic weight of 6.94 and specific gravity of 0.59. It is widely distributed in nature, but is obtained chiefly from the minerals lepidolite and spodumene. Lithium melts at 356°F. It is unstable chemically and burns in the air with a dazzling white flame when heated to just above its melting point. Its salts burn with a crimson flame, and lithium chloride is used in pyrotechnics. Lithium is used for alloying with other metals. It hardens lead by the formation of a compound, $Pb_3Li_2$, and is used in small quantities in bearing metals. See Bahnmetall. Lithium also hardens aluminum alloys, and a very small percentage is used in such strong alloys as Skleron. The metal has also been alloyed with beryllium. An alloy of 65 per cent lithium and 35 beryllium is as light as water but corrodes easily. By adding small quantities of aluminum or zinc the hardness, strength, and resistance to corrosion are increased. Lithium salts are used in storage batteries to increase the electrical capacity. The metal is also used in light-sensitive control cells which depend on the change in resistance of the cell due to varying electron emission with changing light intensity. The cost of lithium is high. A form known as Lithium six consists of the light atoms and is a silvery-white metal of extreme lightness.

**Lithopone.** Also known under various trade names: Ponolith, Beckton white, Zincolith, Sterling white, and others.

A white pigment consisting of about 70 per cent of barium sulphate and 30 per cent of zinc sulphide, but it may contain some zinc oxide. A standard lithopone is 66 per cent barium sulphate and 34 per cent zinc sulphide. High-strength lithopones have more than 30 per cent of zinc sulphide, which latter is one of the whitest pigments. Titanated lithopone contains a percentage of titanium dioxide. Commercial lithopone is a fine-grained white powder used in the manufacture of paints and inks, and as a filler in rubber goods. For paints the powder should pass through a 325-mesh screen. The ground paste should contain 76 to 80 per cent of pigment and 20 to 24 of linseed oil. As a paint pigment, lithopone has good hiding power and is lower in cost than other whites, but is not as durable for outside use as white lead or zinc white. It is the most used white pigment for interior work. It is also used as a filler in oilcloth and linoleum. Albalith is the trade name of the New Jersey Zinc Company for a 70-30 lithopone used as a pigment for rubber goods, in printing inks to give clarity of tone, and for whitening paper.

**Litmus.** A vegetable dyestuff allied to orchil. It is prepared from various varieties of the lichen, *Variolaria*, by allowing them to ferment in the presence of ammonia and potassium carbonate. When completely fermented, the mass assumes a blue color and is mixed with chalk and made up into tablets, or made in paper form. Litmus gives a deep blue color with alkalies and a red with acids, and is used as an indicator of acidity. Azolitmin, $C_7H_7O_4N$, is the coloring matter of litmus, and is a reddish-brown powder.

**Locust.** The wood of the locust tree, *Robinia pseudacacia*, also known as Acacia, False acacia, Black locust, and Red locust. The tree is native to North America, but is also grown in Europe. The wood is strong and durable, with a weight of 43 to 52 lb. per cu. ft. Its hardness is about the same as ash, and the strength and flexibility greater than oak. The grain is coarse, but the surface is lustrous and satiny. Locust is used for furniture, wheel spokes, posts, and in construction. Honey locust is a lighter and weaker wood from the tree *Gleditsia*

*triacanthos*. The name locust is also applied to the wood of the tree *Hymensea courbaril* of tropical America. This wood has a brownish color, with an open grain, and takes a beautiful polish. The wood of the Australian locust, *Acacia melanoxylon*, known as Australian blackwood and Tasmanian blackwood, and employed for cabinetwork, is reddish brown to black in color and beautifully grained. It is similar in durability and appearance to rosewood, but lighter in weight.

**Locust bean gum.** Also called Locust bean flour, and Carob flour. A tasteless and odorless white powder obtained by milling the bean kernels of the locust or acacia trees of America and Europe. When dissolved in water and boiled, it produces an adhesive, transparent jelly, which dries into a colorless, strong elastic film. It is not a starch but is composed of galactan and mannan. It is used for coating textiles and also as a thickener and binder in glues, pastes, and latex, in leather finishes, and in sizings for yarns and paper. The flour is marketed in 50, 100, 150, and 175 mesh. It dissolves in cold water and swells in warm water. The flour is edible and is also used in jellies and foodstuffs.

**Logwood.** An extract obtained from the wood of the tree, *Hæmatoxylon campechianum*, of tropical America, used as a black dye or as a darkening agent in browns and grays. The wood yields 15 per cent of extract. The coloring matter, Hematine, $C_{16}H_{12}O_6$, forms brownish-red crystals and is only produced in the aged wood or by oxidation of the white extract of fresh wood. Logwood, or Hematine, is marketed in crystals, solid extract, or water extract.

**Low brass.** Originally called Dutch metal for jewelry. One of the standard alloys of the brass mills. It contains 80 per cent of copper and 20 of zinc, has a golden-yellow color, is very ductile and easily drawn. It is used for formed and drawn parts that require a high finish. The tensile strength when annealed is 44,000 lb. per sq. in. and elongation 60 per cent; the tensile strength, hard-rolled, is 75,000 lb. with elongation of 12 per cent. The weight is 0.313 lb. per cu. in.

**Low-expansion alloys.** Alloys, usually of nickel and iron, which have a very low coefficient of expansion at ordinary temperatures, used chiefly for instrument parts and for lead wires to be sealed in glass or other material. They were first developed in France. See Invar. Elinvar, used for chronometer balances and springs for gages and instruments, has low thermal expansion and almost invariable modulus of elasticity. Elinvar for hair springs for watches contains 33 to 35 per cent of nickel, 53 to 61 of iron, 4 to 5 chromium, 1 to 3 tungsten, 0.5 to 2 manganese, 0.5 to 2 silicon, and 0.5 to 2 carbon. Platinite, a French alloy with a coefficient of expansion about the same as that of glass, contains 46 per cent nickel and 54 iron. It is produced by S. A. Commontry-Fourchambault and used in light bulbs. Dilver and Adr are also low-expansion, nickel-iron alloys of the same company. Dumet is an alloy of 40 per cent nickel and 60 iron, with a coating of oxidized copper on the wire to give greater adhesion to the glass. These alloys also have the characteristics of high strength, corrosion resistance, and heat resistance, and are suitable for electric resistance wires. See Resistance wire.

The term, Low-expansion alloy, is also used for aluminum alloys specially alloyed for such uses as automotive pistons to give the same expansion as iron. Lo-Ex alloy, also known as Alloy No. 132, of the Aluminum Company of America, is used for casting automotive pistons. It has a low coefficient of expansion, about 0.0000105, nearly that of cast iron. The alloy contains 14 per cent of silicon, 1 of copper, 1 of magnesium, and 2 of nickel. It has high wear resistance, and in the United States this type of alloy is used to replace the modified silicon alloys used in Europe. The tensile strength is from 30,000 to 50,000 lb. per sq. in. and Brinell hardness from 90 to 140, depending upon the heat-treatment. The specific gravity is 2.69. Alloy No. 1003, of Aluminum Industries, Inc., is a similar casting alloy containing also 1 per cent of iron.

**Lubricating grease.** Usually a compound of a soap with a mineral oil, employed for lubricating machinery where the speed is slow or where it is not possible to hold a free flowing oil. The soap is made with fatty oils or fats containing stearin,

olein, or palmatin. Lime is used to form a soap insoluble in water, or an insoluble mineral soap is used. Aluminum stearate gives high film strength and uniformity to the grease. Mineral lubricating grease usually contains 80 to 90 per cent of mineral oil and the remainder, lime soap. Federal specifications prescribe 85 per cent of mineral oil. True Grease, however, is produced from hog fat and condemned pork material. It is similar to lard in appearance and odor but may be darker in color, and is not passed for human consumption. It is in various grades from Grade A, white, to brown grease. The residue is marketed as white grease stearin. Thick greases made at high temperatures from animal fat with soda form very resistant films and are unsuitable for lubrication. Fillers in the cheaper greases, such as resin, wax, and talc, are not good lubricants and are likely to have abrasive action. The stiffness of a grease should be obtained with mineral soap. A.S.T.M. specifications for heavy journal bearing grease require 45 per cent soap content. Hard grease flows at a temperature of about 90°C.; medium grease flows at 75 to 80°C. Paraffin wax, sometimes added, is an adulterant and not a lubricant. Graphite grease contains 2 to 10 per cent of amorphous graphite, and is used for bearings, especially in damp places. Federal specifications call for 2 to 3 per cent of graphite. For large ball and roller bearings a low-lime grease is used, sometimes mixed with a small percentage of graphite. Cylinder grease is made of about 85 per cent of mineral oil or mineral grease and 15 per cent of tallow. Compounded greases are also marketed containing animal and vegetable oils, or are made with blown oils and compounded with mineral oils. The fatty acids in vegetable and animal oils, however, are likely to corrode metals. Tannin holds graphite in solution; in the gear grease sold under the name of Gredag by the Acheson Oildag Company a graphite-tannin mixture is used. Metaline, of the R. W. Rhoades Metaline Company, Inc., is a compound of powdered antifriction metal, oxide, and gums, which is packed in holes in the bearings to form self-lubricating bearings.

Sett greases are a mixture of the calcium soaps of rosin acids with various grades of mineral oils. They are low-cost semi-solid

greases used for lubricating heavy gears or for greasing skidways. Clay fillers may be added to improve the film strength, or copper or lead powders may be incorporated for heavy load conditions. Solidified oil is also a name given to grease made from lubricating oil with a soda soap and tallow, used for heavy bearings. Cup grease is made with soda soap and light lubricating oils. Greases made with potash and soda soaps tend to form soap fibers when water is present. In this industry a metallic soap that contains no fibers is called a Neat soap, and gives a smooth grease.

**Lubricating oils.** Oils used for lubricating the bearing parts of machinery. They are usually the heavy distillates following kerosene in the fractional distillation of petroleum, between the temperatures 253 and 317°F. They are separated into grades, light, medium, and heavy, depending upon the molecular weight. They are also classed as pale, when yellow to reddish, and dark, when brownish black in color. The flash points range from 300 to 600°F., and the specific gravities usually from 0.860 to 0.940. Lubricating oils may be bleached with acid, and they may be mixed with vegetable or animal oils. Animal oils are more greasy than mineral oils, but they are acid. Vegetable oils are greasy and have more oilness, but they oxidize easily and are also acid. They are likely to gum in use unless an antioxidant is used. Vegetable and animal oils add the property of adhesion to the lubricating oil, but in no case should any element be added to an oil that will cause emulsification. Federal specifications for marine engine oil call for 15 to 20 per cent of blown refined rapeseed or peanut oil. This lubricating oil has a flash point of 350°F. Steam cylinder oil has 5 to 10 per cent of fatty acid vegetable oils, and the flash point is 450°F. High percentages of animal or vegetable oils may be added to lubricating oils for use on textile machinery. They are called Stainless oils for this purpose, since such oils wash out of the textile more easily than mineral oils. They also give lower coefficients of friction. Absorbed oil is a trade name of E. F. Houghton & Company for a combination oil, one oil acting as a film and the other as a lubricant.

The nature of the bearing metals often has an effect upon the action of the lubricating oil. In highly alloyed metals some elements act as catalyzers to oxidize the oil, or the acids or moisture in the oils may act to break down the metal. In lead-bearing metals free magnesium causes disintegration of the lead in contact with moisture. The alkali-lead metals also tend to dissolve in contact with animal or fish oils. Normally, however, none of the white bearing metals are attacked by the animal and vegetable oils used for lubrication unless there are perceptible amounts of a freely oxidizing element present. Graphite adds to the effectiveness of a lubricating oil and can be held in suspension with a tannin. Oildag, of the Acheson Colloids Corporation, is a graphite-tannin mixture in oil. Glydag, of this company, is a solution of 10 per cent of graphite in glycerin, used as a low-temperature lubricant. Amlo is the trade name of a mineral oil refined wax free, used for low-temperature lubrication. Antioxidants used in oils to reduce oxidation and minimize sludging and acid formation are usually tin compounds such as tin dioxide, tin tetraphenyl, and tin ricinoleate. Tin dust alone has also an inhibitory action. Tetraethyl lead is an effective antioxidant for high temperatures.

**Lutes.** Adhesive substances, usually of earthy composition, employed for closing pipe joints or seams to make them tight, or for coating pipes or boilers to protect them from high temperatures. Various clays are used for this purpose, or white lead and oil. Plaster of paris mixed with a weak glue will withstand a dull red heat. Fat lute is pipe clay mixed with linseed oil. Linseed meal with lime is also used. Many prepared compounds for this purpose are marketed under trade names. See also Spence's metal.

The term also properly belongs to the class of adhesive used for sealing-in wires in light bulbs, and sealing over connections in electrical apparatus. These lutes are usually compounds of sodium silicate with a filler, but they may also be compounds of mineral waxes or bitumen mixtures.

**Machinery steel.** Also called Machine steel. An old shop term for open-hearth steel having low-carbon range, not over

0.25 per cent. See Ingot iron and Carbon steel. They have tensile strengths from 35,000 to 45,000 lb. per sq. in. Machinery steel will not harden, but can be carburized on the outside by packing in bone black or other carbon material and heating in a furnace. It is then casehardened by quenching. When properly heat-treated, it has a fine grain, giving good wearing qualities on the outside and a tough core. It is used for machinery parts, gears, and cheap dies for cutting paper and thin sheet metal and for gages to be pack hardened. Machinery steel can be forged readily, and also machines easily. Small amounts of phosphorus make it free cutting and keep the chips from curling. Some special grades of machinery steel contain 0.40 to 0.60 per cent of carbon, having a tensile strength up to 60,000 lb. per sq. in. They are used for shafts, forgings, and machine parts where toughness and stiffness are required.

Modern machinery parts are now most frequently made of tougher and harder steels, and the term Machinery steel is applied to steels containing some alloying elements. Jessop's Extra Tough No. 4 is called by the maker Special alloy machinery steel. It contains 0.60 to 0.70 carbon and small amounts of chromium, nickel, and molybdenum. Rytense AA machinery steel, of Joseph T. Ryerson & Son, Inc., is a special analysis steel with a tensile strength up to 115,000 lb. per sq. in., elongation of 20 per cent, and Brinell hardness of 229. Economo steel, of Wheelock, Lovejoy & Company, Inc., is a low-carbon machinery steel containing 0.18 per cent of molybdenum, which is intended to produce a tough core when casehardened. The Automotive machine steels consist of five grades from S.A.E. 1010 to S.A.E. X1020.

Max-El 1B steel, of the Crucible Steel Company, has 0.20 carbon, high manganese, and a small amount of molybdenum. Max-el 3½ steel has 0.50 carbon, 0.50 chromium, 1.0 manganese, and some molybdenum. All of these steels are marketed as Machinery steel, which makes the term now mean any steel intended to be used for machinery parts without heat treatment or with minimum simple heat treatment, especially casehardening steels. Even some alloy steels, when used for casehardening, are termed machinery steel. A carburizing steel used for molds for

plastics is S.A.E. steel 3312, containing 3.5 per cent of nickel and 1.2 chromium. Low-alloy machinery steels are used for tools to be hobbed. Hoballoy, of the Crucible Steel Company, is a chrome-nickel steel of this type with 0.10 carbon. When casehardened it has a very hard case and a tough core. Plastalloy, of Henry Disston & Sons, Inc., is a low-carbon, low-alloy, fine-grained steel used for molds to be hobbed.

Structural steel was formerly simple low-carbon steel of the same type as machine steel, but is now largely high-tensile manganese steel or low-alloy, low-carbon steel. N-A-X high tensile steel, of the Great Lakes Steel Corporation, has the typical composition: Carbon 0.13 per cent; manganese, 0.70; silicon, 0.80; copper 0.23; chromium, 0.60; nickel, 0.15; molybdenum, 0.10; zirconium, 0.12. In structural shapes it has a tensile strength of 80,000 lb. per sq. in. with elongation of 24 per cent, and is resistant to fatigue.

**Mack's cement.** A hard, durable cement consisting of dehydrated gypsum to which a small percentage of calcined sodium sulphate, $Na_2SO_4$, or potassium sulphate, $K_2SO_4$, has been added. The amount of sulphate is usually about 0.4 per cent. The cement sets quickly, and adheres well. It is used chiefly for covering wire mesh on walls and ceilings, and for flooring when mixed with sand or clinker. It is not porous, and will not absorb oil paints well.

**Madder.** Formerly the most important dyestuff with the exception of indigo. It is now largely replaced by the synthetic dye Alizarin. It was originally known by its Arabic name Alizari and by the name Turkey red. Madder is the ground root of the plant *Rubia tinctorum*, which has been stored for a time to develop the coloring matter, the orange-red alizarin, $C_{14}H_{18}O_4$. Purpurin, $C_{14}H_{18}O_5$, is also developed, but this is now also produced synthetically. Madder gives fast colors.

**Madia-seed oil.** A drying oil obtained from the seeds of the plant *Madia sativa*, native to California. It is similar to the sunflower, and the seeds and oil have similar properties. The seeds contain up to 35 per cent of a yellowish-brown oil

of the semidrying type. The cold pressed oil has a pleasant taste and is edible. The oil is used in paints and in blends.

**Magnalium.** The name of one of the first of the aluminum-magnesium alloys, invented by Dr. Ludwig Mach. The original Mach's metal contained up to 10 per cent of magnesium. Magnalium contains about 5 per cent of magnesium, has a specific gravity of 2.63, tensile strength of 22,000 lb. per sq. in., and elongation of 4 per cent. A modification contained less magnesium and had other elements, giving higher strength. The Germans were early interested in magnesium alloys because of the lack of aluminum and the availability of magnesium. The alloys now employed contain less magnesium, with other elements. Anticorodal is a corrosion-resistant aircraft alloy containing only 0.5 per cent of magnesium, 0.5 manganese, 1 silicon, and the balance aluminum. See also Aluminum alloy and Aluminum-magnesium alloy.

**Magnesia cement.** Magnesia oxide, MgO, prepared by heating the chloride or carbonate to redness. When mixed with water, it sets to a rigid mass and is used for covering steam pipes or furnaces. The term 85 per cent Magnesia, applied to a pipe covering, generally means 85 per cent of hydrated magnesia cement or magnesium carbonate with 15 per cent of asbestos fibers. Magnesia cement is also mixed with lime for mortar and is also used for firebricks.

**Magnesite.** A mineral used in the manufacture of bricks for basic refractory furnace linings and as an ore of magnesium. The ground magnesite is a light powder, is shaped into bricks at high pressure, and baked in kilns. Magnesite is a magnesium carbonate, $MgCO_3$, with some iron carbonate and ferric oxide. See also Magnesium carbonate.

It is sold on the basis of the MgO content. British India magnesite has 92.7 per cent magnesia. Manchurian dead-burned magnesite has 90.9 per cent magnesia with 4 per cent silica, and some iron oxide and aluminum oxide. Brucite, a natural hydrated Magnesium oxide found in Ontario, contains a higher percentage of magnesia than ordinary magnesite and is used for furnace linings. Austrian magnesite has from 4 to 9 per cent of

iron oxide, which gives it the property of fritting together more readily. Magnesite occurs in compact earthy forms, or in granular masses. Its hardness is 3.5 to 4.5, and its specific gravity is 3.1. It has a vitreous luster, and the color is white, gray, yellow, or brown. It fuses at 2165°C. The high melting and softening points of magnesite, and its chemical resistance make it a valuable refractory. The chief disadvantage is its low resistance to sudden temperature changes. The American production of crude magnesite is in Nevada, Washington, and California. Magnesite materials are usually sold under trade names. It is also employed as an insulating covering for steam pipes; the pure magnesium carbonate is used in boiler compounds. Ritex is a magnesite brick having strong basic characteristics, which is marketed by the General Refractories Company. Magnesite is also used in Germany to produce the artificial stone known as Kunststein. Ramix is the name of a magnesite refractory of Basic Dolomite, Inc. Basifrit is a name given to impure Canadian magnesitic dolomite.

**Magnesium.** The lightest metal that is stable under ordinary conditions and produced in commercial quantities. It was originally called Magnium by Sir Humphrey Davy. It is the sixth most abundant element and is only two-thirds as heavy as aluminum. The chemical symbol is Mg. It resembles aluminum in color and properties. Its specific gravity is 1.74. It has a tensile strength when cast of 14,000 lb. per sq. in., an elongation of 5 per cent, and a compressive strength of 30,000 lb. per sq. in. When rolled, it has a tensile strength of 25,000 lb. per sq. in. and an elongation of 4 per cent. The strength is somewhat higher in the forged metal. The Brinell hardness of the cast metal is 30, and of the rolled 40. The melting point is 651°C. and boiling point 1120°C. Magnesium is too brittle to roll cold, but can be rolled at 300 to 500°C. Rolled sheet is made in thickness down to 0.005 in. It is the easiest machining of the metals and is employed for light alloys, especially for airplane and automobile engine use, either as a major constituent or in aluminum alloys. It has also been found to be a good metal for sound-producing resonators. It is immune to attack by alkalies, and is resistant to the action of sea water.

Magnesium ingot is marketed 99.9 pure but the metal is not ordinarily used alone, but is alloyed with aluminum. It alloys with most common metals except those in the iron and chromium groups. The pure metal ignites easily, and even when alloyed with other metals the fine chips in machining must be guarded against fire. In alloying it cannot be mixed directly into molten metals because of flashing, but is used in the form of master alloys. The specific gravity of an alloy with about 10 per cent of aluminum is approximately 1.8. Magnesium is also used as a deoxidizer in casting various metals, and is used for Flashlight powders and fireworks. It burns readily, with an intense flame, to magnesia. For flares magnesium gives a brilliant light of high actinic value. The speed of ignition increases rapidly with decreasing particle size. A 200-mesh powder is used for flashlights, and 30 to 80 mesh for more slowly burning aerial rockets and flares. Magnesium is produced commercially by the electrolysis of a fused chloride or fluoride-oxide. Much of the magnesium in the United States is produced from brine wells in Michigan. The natural brine contains 3 per cent $MgCl_2$, 9 per cent $CaCl_2$, 14 per cent NaCl, and 0.15 per cent bromine. In Russia magnesium is produced from the mineral Carnallite, and in Germany from magnesite, carnallite, and dolomite, and from the end lyes of the potash industry. In Japan it is produced from sea water.

**Magnesium alloy.** An alloy of magnesium, usually with aluminum, noted for extreme lightness, the specific gravity seldom exceeding 1.83. The alloys are easily machined and are used for aircraft engine parts, pistons, propellers, and structural shapes, where weight saving is an important factor, or where light reciprocating parts are required. Wrought alloys usually contain aluminum and manganese; forgings contain aluminum, manganese, and zinc; and die-casting alloys contain aluminum, manganese, and silicon. Aluminum up to 8 per cent refines the grain, increasing hardness, strength, and rigidity; with higher percentages the alloys become brittle. Zinc has a somewhat similar effect. Small amounts of manganese give added corrosion resistance and strength. Some alloys with no aluminum have

as high as 1.5 per cent of manganese. Cadmium improves the physical properties of the casting and extruding alloys, and a patented alloy contains up to 6 per cent of cadmium. Copper softens but weakens the structure.

Alloy AM240, of the Aluminum Company of America, has 9 to 11 per cent of aluminum and 0.10 manganese. It is for sand and permanent-mold castings, and has a tensile strength of 20,000 lb. per sq. in. with elongation of 2 per cent. Alloy AM403, for sand castings, has 1.2 to 2 per cent of manganese with no aluminum. The tensile strength is 14,000 lb. per sq. in. and elongation 5 per cent. This alloy in hot-rolled sheet has a tensile strength of 34,000 lb. per sq. in. Alloy AM74S, for forgings, has 2.5 to 3.5 per cent of aluminum, 0.2 manganese, and 2.5 to 3.5 zinc. When aged it has a tensile strength of 42,000 lb. per sq. in. and elongation of 14 per cent. Elektron, produced by I. G. Farbenindustrie, contains 85 to 96 per cent of magnesium, 9 to 11 aluminum, 4 zinc, and up to 2.5 manganese. The British Air Ministry specification for "Electron" calls for 1.3 to 1.7 per cent of manganese and the remainder magnesium. Dowmetal M has this composition, with tensile strength of 45,000 lb. per sq. in. Alloys containing 6 per cent of aluminum, 3 zinc, and small amounts of manganese have good salt-water resistance. They have tensile strengths, as cast, up to 30,000 lb. per sq. in., which by heat treatment can be increased to 42,000 lb. per sq. in. with added hardness up to 70 Brinell. Dowmetal H, of the Dow Chemical Company, and Mazlo alloy AM265, of the Aluminum Company of America, are of this type. Dowmetal B has 12 per cent of aluminum. Dowmetal F has 4 per cent of aluminum and 0.3 manganese. In extruded rod it has a tensile strength up to 42,000 lb. per sq. in. Bohnalite XA, of the Bohn Aluminum & Brass Company, has 6 per cent of aluminum and 0.50 manganese. Dowmetal R is a die-casting alloy having 8.5 to 9.5 per cent of aluminum, 0.13 manganese, and 0.6 zinc, noted for toughness and easy casting.

**Magnesium carbonate.** A light, white, insoluble powder of the composition $MgCO_3$, containing also crystals with water of crystallization. The specific gravity is 3.10. It is made by

calcining dolomite with coke, slaking with water, saturating with carbonic acid gas, and crystallizing out the magnesium carbonate. It is employed as an insulating covering for steam pipes and furnaces, for making oxychloride cement, in boiler compounds, and as a filler for rubber and paper. Montax, of the R. T. Vanderbilt Company, used as a filler, is a mixture of hydrated magnesium carbonate and silica. Federal specifications for "magnesia" call for this hydrated magnesium carbonate of a composition of $4MgCO_3 \cdot Mg(OH)_2 5H_2O$, combined with 10 per cent of asbestos fibers, for use as a heat-insulating block. See Magnesia. Thermax is the name of magnesia insulating materials of the Northwest Magnesite Company.

**Magnesium-nickel.** An alloy of magnesium and nickel used for adding nickel to magnesium alloys and for deoxidizing nickel and nickel alloys. A magnesium-nickel marketed by Alloys and Products, Inc., contains about 50 per cent of each metal, is silvery white in color, and is furnished in round bar form. Magnesium-Monel made by the same company contains 50 per cent of magnesium and 50 of Monel metal. Alloys of magnesium with nickel, Monel, zinc, copper, or aluminum, used for deoxidizing and cleaning nonferrous metals, are called Stabilizer alloys.

**Magnesium powder.** A fine powder for pyrotechnic and chemical uses, made by reducing metallic magnesium into particles in the shape of curly shavings to give maximum surface per unit of weight. It is produced in four grades: Cutting powder, Standard powder, Special specification, and Fireworks powder. Cutting powder is finely cut shavings in a matted condition, made from magnesium of 99.8 per cent purity. Standard powder is loose powder in fineness from 10 to 200 mesh. Fireworks powder is 100 mesh. Incendiary powder, for small-arms incendiary ammunition, is magnesium powder mixed with barium peroxide. Ophorite is a British name for magnesium powder and potassium perchlorate used as an igniter for thermite incendiary bombs. See also Flashlight powder.

**Magnesium sulphate.** A sparkling white, bitter-tasting product occurring in needle-shaped crystals, known in the drug

trade as Epsom salt, and in mineralogy as Epsomite It is employed industrially in leather tanning, as a mordant in dyeing and printing textiles, for filling cotton cloth, sizing paper, and in water-resistant and fireproof magnesia cements. The chemical formula is $MgSO_4 \cdot 7H_2O$, or anhydrous $MgSO_4$. The specific gravity is 1.678 and 2.65, respectively. It occurs naturally as deposits from spring waters, and is also made by adding sulphuric acid to magnesite. In Germany it is produced from the mineral Kieserite, $MgSO_4 \cdot H_2O$, which is abundant in the Strassfurt district, and is used as a source of sulphuric acid and of magnesium.

**Magnet steels.** Steels employed for making permanent magnets, that is, magnets that retain their magnetism after they are removed from the magnetic field, as distinct from electromagnets, which are of soft iron and are only magnetized while in the magnetic field. Magnet steels were originally good grades of crucible tungsten steel, sometimes containing chromium and manganese. Tungsten magnet steels contain 5 to 6 per cent of tungsten, and about 0.65 per cent of carbon, and are hardened in water without drawing the temper. They are "aged" by heating in oil to a temperature of about 250°F., and then placed in a vibrating device. With increased carbon the coercive force increases, but the maximum induction and the residual magnetism decrease. Molybdenum may be used instead of tungsten in magnet steels. Molybdenum-iron magnet alloys have been made with 20 or more per cent of molybdenum having high residual magnetism and high coercive force.

Chromium magnet steels are less expensive, and contain up to 5 per cent of chromium, usually 3 per cent, and about 1 per cent of carbon. A standard grade contains 2.25 to 4 per cent chromium, 0.45 manganese, and 0.95 carbon. The magnetic properties are similar to those of the tungsten steels, and they have the same difficulty in hardening because of breakage when the carbon is high. Cobalt magnet steels contain from 18 to 60 per cent of cobalt, part of which may be replaced by the less expensive chromium, or some tungsten may be used. Some cobalt magnet steels contain 1.5 to 3 per cent of chromium,

3 to 5 of tungsten, 0.50 to 0.80 carbon, with high cobalt. A Japanese alloy, K.S. magnet steel, contains 30 to 40 per cent of cobalt, 5 to 9 tungsten, 1.5 to 3 chromium, and 0.4 to 0.8 carbon. The coercive force of this steel is about three times that of a 5 per cent tungsten steel. Cobalt steel and Cobalt-chromium magnet steel may contain some molybdenum, which gives them air-hardening properties. A typical steel contains 1.5 per cent of molybdenum. Permanite is the trade name of a cobalt-chromium magnet steel containing tungsten. Armat is a magnet steel marketed by the Jessop Steel Company. Alnico is an aluminum-nickel-cobalt-iron alloy developed by the General Electric Company in which precipitation hardening occurs with AlNi crystals dissolved in the metal. It has very high coercive force. Magnetic powder is finely divided particles of a material made by boiling 80 parts of nickel and 20 iron in the presence of oxygen, rolling, and then reducing.

**Mahoe.** Also called Blue mahoe. The wood of the tree *Hibiscus elatus*, of tropical America, employed for making gunstocks as a substitute for walnut. The timber is available in large logs. The wood has a gray-blue color, or sometimes brownish gray with streaks, and an aromatic odor. It is hard, with a coarse, open grain.

**Mahogany.** A name applied to a variety of woods. All of the true mahogany, however, comes from trees of the family *Meliaceae*, but of various genera and species. The tropical cedars, Spanish cedar and Paraguayan cedar, belong to this family. Mahogany, of the tree *Swietenia mahogani*, and other species of *Swietenia*, known as Spanish mahogany, is obtained from Mexico to as far south as northern Argentina. The Central American has the best reputation and is frequently referred to under the Spanish name Caoba. Baywood is an English name originally applied to a superior, straight-grained mahogany from the shores of the Bay of Honduras. Colombian mahogany is the wood of the tree *Cariniana pyriformis* of northern South America. It resembles mahogany but is heavier and harder. Mahoganies from tropical Africa, chiefly *Khaya senegalensis*, are sold under the names of the shipping ports.

The wood of the mahogany tree is obtainable in large logs. It has a reddish color of various shades. The grain is often figured, and it has a high luster when polished. It seasons well and is much prized for furniture and cabinetwork. It is often used for small patterns in foundry work where they must be employed frequently and should not alter in shape. The cheaper grades are used for this purpose. The weight varies from 32 to 42 lb. per cu. ft. The hardness and closeness of the different mahoganies also vary considerably. The beautiful curled grain specimens are obtained from selected forks or crotches of the trees.

The various species of mahogany formerly used for airplane propellers were either African *Khaya* or American *Swietenia*, with average specific gravities kiln-dried of 0.47 to 0.51. The compressive strength is up to 1,760 lb. per sq. in. perpendicular to the grain, and the shearing strength 860 lb. per sq. in. parallel to the grain. Australian red mahogany is from the tree *Eucalyptus resinifera* of Australia. It is hard, durable, of a dark-red color, with a coarse, open grain. Crabwood, used as a substitute for mahogany, is the wood of the carapa tree, *Carapa guianensis*, of tropical America. It has a deep reddish-brown color with a coarse grain and weighs 40 lb. per cu. ft.

**Malachite.** Also known as Green copper carbonate. An important ore of copper. It is a basic carbonate of copper, $(Cu{\cdot}OH)_2CO_3$, containing theoretically 57.4 per cent of copper. The structure of the mineral is usually radiating fibrous. It has a hardness of 3.5 to 4 and a specific gravity of 3.0 to 4.1. The color is bright green. In crystal form it has a vitreous luster, but in the earthy form it is dull.

**Malleable iron.** A high-tensile-strength white cast iron produced by a long heat treatment of white chilled castings. Iron for malleable iron is usually melted in the reverberatory furnace, which gives it greater strength and ductility than iron melted in the cupola in contact with the fuel. The iron contains 1 to 1.5 per cent of silicon and is cooled rapidly to produce white iron. The castings seldom exceed 10 lb. in weight. After casting, the parts are packed in annealing pots with hammer scale or

mill scale, or oxidized turnings or borings, and subjected to an increasing temperature to about 1650°F., for a period of 48 to 60 hr. They are then cooled slowly with temperature decreasing 8 to 10°F. per hour to below 1275°F. The resulting iron has the carbon in regular tiny particles instead of flakes as in gray cast iron. With high annealing temperatures and a long annealing period the total carbon is reduced in the shell resulting in a coarse-grained casting known as Whiteheart which has reduced strength. The ordinary American malleable iron called Blackheart has a white shell and a dark core, the outside being completely decarbonized. Slight additions of copper accelerate the annealing of blackheart iron. An iron known as Quick malleable iron, used for automotive engine castings, has 2.2 per cent of carbon, 1.5 silicon, 0.30 to 0.60 manganese, and 0.75 to 1.0 copper. The copper also increases the tensile strength.

For ease of machining, malleable iron normally should have 2.60 per cent or more of carbon, although less carbon is desirable for strength and ductility. An average composition is carbon, 2 per cent; silicon, 0.60 to 1.10; manganese, under 0.30; phosphorus, under 0.20; and sulphur, 0.06 to 0.15. About 1 per cent of copper is used for corrosion-resistant castings.

Malleable iron is used for castings, for implements, pipe fittings, building hardware, and small machine parts requiring strength. The tensile strength is about 50,000 lb. per sq. in., elongation 15 per cent, and Brinell hardness 115. Federal specifications call for two grades, with strengths of 50,000 and 53,000 lb. per sq. in. Modern pearlitic malleable iron, with a matrix of pearlite and temper carbon, will have a minimum tensile strength of 60,000 lb. per sq. in and elongation of 12 per cent. Malleable irons are sold under trade names. Certified malleable iron, of the Erie Malleable Iron Company, has a tensile strength up to 57,000 lb. per sq. in. and hardness up to 120 Brinell. Promal is a specially processed malleable iron of the Link-Belt Company, used for chain links. The hardness is up to 170 Brinell, and it has high fatigue resistance. Supermal, of the Jeffrey Manufacturing Company, is a similar type of iron. Flecto iron, of the Ohio Brass Company, is a malleable iron specially annealed to prevent brittleness when hot galvanized. Z-metal,

of the Arcade Malleable Iron Company, used for pump and chemical machine parts, has a tensile strength up to 80,000 lb. per sq. in. and a hardness of 180 Brinell. Belmalloy is the trade name of an electric-melted pearlitic malleable iron.

**Manganese.** A metallic element, symbol Mn, found in the minerals manganite, pyrolusite, and others, with most iron ores and traces in most rocks. Manganese has a silvery-white color with purplish shades. It is very brittle. Distilled manganese, with no iron, and with carbon and silicon not over 0.006 per cent total, has a fine silvery-gray luster very resistant to corrosion. It is brittle but hard enough to scratch glass. The specific gravity is 7.42, melting point 2237°F., and weight 0.268 lb. per cu. in. It is used in the steel industry as a deoxidizer and as a hardener, and nearly all steel now contains some manganese. For this purpose it is used largely in the form of ferromanganese. Manganese is also added to steel in considerable amounts for the production of wear-resistant alloy steels.

The American consumption of manganese ore is 800,000 tons annually, of which 750,000 tons are used for deoxidizing and alloying with steel and bronze and 50,000 tons are used in dry-cell batteries, bricks, glass, chemicals, and paints. Most of the ore comes from Russia, Brazil, Gold Coast, Cuba, and India. The American ores from the Southeast and Northwest are generally low grade, with 5 to 10 per cent of metallic manganese; Montana manganese ore is used for dry batteries and is also concentrated by a special nodulizing process up to 58 per cent manganese. In Germany, low-grade ore is made into ferromanganese by first smelting to spiegeleisen and then treating part in a basic and part in an acid converter before mixing. Manganese metal, for adding manganese to nonferrous alloys, is marketed in crushed form containing 95 to 98 per cent of manganese, a maximum of 2 to 3 per cent of iron, a maximum of 1 per cent of silicon and 0.25 maximum of carbon. Manganese powder is powdered metal of high purity, of 150 to 325 mesh, employed for pyrophoric and metallurgical uses. A Manganese-boron, containing 20 to 25 per cent of boron, is employed for deoxidizing and hardening bronzes. It also contains small

quantities of iron, silicon, and aluminum. Ferro-grade manganese ore should contain 35 per cent or more of manganese.

**Manganese-aluminum.** A Hardener alloy employed for making additions of manganese to aluminum alloys such as Duralumin. Manganese lowers the thermal conductivity of aluminum but increases the strength and increases the contraction. Manganese up to 1.5 per cent is used in aluminum alloys when strength and stiffness are required. A manganese-aluminum marketed by the Niagara Falls Smelting and Refining Corporation contains 25 per cent of manganese and 75 aluminum.

**Manganese bronze.** A brass containing iron and manganese which, because of its hardness and crystalline structure, is called a bronze. It casts easier than aluminum bronze and is used for propeller blades, valve stems, engine frames, and machinery parts requiring high strength and resistance to sea water. Manganese is a deoxidizer in the alloys, but in excess, usually up to 3.5 per cent, it hardens and strengthens the alloy, increases the solubility of the iron in the brass, and acts to stabilize the aluminum when this metal is used. Manganese has nearly the whitening power of nickel in copper alloys. A.S.T.M. and Federal specifications for manganese bronze call for 55 to 60 per cent of copper, 38 to 42 zinc, up to 3.5 manganese, up to 1.5 tin, 1.5 aluminum, and up to 2 iron. This alloy has a minimum tensile strength of 65,000 lb. per sq. in. and elongation of 30 per cent as cast; the wrought metal has a strength of 72,000 lb. per sq. in. Even very small amounts of lead decrease the strength of manganese bronze and lower the ductility. Phosphor copper is sometimes added to make the metal easier pouring. Manganese bronze has high shrinkage, $\frac{3}{16}$ in. per ft., and large fillets are necessary between changes in section thickness. A Super manganese bronze, used by the Wright Aeronautical Corporation, contains 69 per cent of copper, 20 zinc, 2 manganese, 2.5 iron, and 6.5 aluminum. It has a tensile strength of 110,000 lb. per sq. in. and Brinell hardness of 225 when heat-treated. A Manganese-aluminum brass, under the name of Hy-Ten-Sl, marketed by the American Aluminum Bronze Company, contains 66 per cent of copper, 19 zinc, 10 aluminum, and 5 manganese.

The castings have a tensile strength up to 105,000 lb. per sq. in., elongation 15 per cent, and Brinell hardness up to 175. It is also marketed in wrought forms.

**Manganese casting brass.** A brass, usually muntz metal, containing a small amount of manganese, with or without iron and tin. It has a high tensile strength and will make clean, dense castings. An alloy used by one automotive company has 58 per cent of copper, 40 zinc, and 2 of a master alloy consisting of tin, iron, manganese, and aluminum. The lead content is not permitted to exceed 0.15 per cent. The tensile strength is 70,000 lb. per sq. in. and elongation 20 per cent. It is used as a substitute for malleable iron or drop-forged steel. Lumen manganese brass, of the Lumen Bearing Company, is a 60–40 brass with 3 per cent of the copper replaced with 1 per cent of iron and small amounts of manganese, tin, and aluminum.

**Manganese copper.** An alloy of the metals manganese and copper, containing usually 25 or 30 per cent of manganese, used as a deoxidizer in making nonferrous alloys, especially brass, cupro-nickel, and German silver, and also for adding manganese to manganese bronze. The best grades of manganese copper are made from metallic manganese and are free from iron. For nickel bronzes and nickel alloys the manganese copper must be free of both iron and carbon, but grades containing up to 5 per cent of iron can be used for manganese bronze. Grades made from ferromanganese contain iron. Manganese copper is usually marketed in slabs with notched sections, or as shot. It has a lower melting point than metallic manganese and is thus more easily dissolved in the brass or bronze. The 30 per cent alloy melts at about 1600°F.

**Manganese green.** The common name for Barium manganate, $BaMnO_4$, a green powder used as a paint pigment. It is also known as Cassel's green. It is poisonous, insoluble in water, and has a specific gravity of 4.85. It is made by heating manganese dioxide, barium nitrate, and barium sulphate.

**Manganese steel.** All commercial steels contain some manganese which has been introduced in the process of deox-

idizing and desulphurizing with ferromanganese, but the name was originally applied only to steels containing from 10 to 15 per cent of manganese. Steels with from 1.0 to 1.5 per cent of manganese are known as Carbon-manganese steel, Pearlitic manganese steel, or Intermediate manganese steel. Medium manganese steels, with manganese from 2 to 9 per cent, are brittle and are not ordinarily used.

The original Hadfield manganese steel made in 1883 contained 10 to 14.5 per cent of manganese and 1 per cent of carbon. Manganese increases the hardness and tensile strength of steel. In the absence of carbon, manganese up to 1.5 per cent has only slight influence on iron; as the carbon content increases, the effect intensifies. Air hardening becomes apparent in a 0.20 carbon steel with 1.5 per cent of manganese, and in a 0.35 carbon steel with 1.4 per cent of manganese. The manganese steels used for dipper teeth, tractor shoes, and wear-resistant castings, contain 10 to 14 per cent of manganese, 1 to 1.4 carbon, and 0.30 to 1 per cent of silicon. The tensile strength is up to 125,000 lb. per sq. in., elongation 45 to 55 per cent, weight 0.286 lb. per cu. in., and Brinell hardness, when heat-treated, of 185 to 200. Cold-working hardens this steel, and dipper teeth in service will work-harden to a hardness up to 550 Brinell.

High-manganese steels are not commercially machinable with ordinary tools, but can be cut and drilled with tungsten carbide and super-high-speed tools. The Austenitic steels, with about 12 per cent of manganese, are exceedingly abrasion resistant and harden under the action of tools. They are non-magnetic. The coefficient of expansion is about twice that of ordinary steel. Various trade names are used to designate the high-manganese steels. Rol-man steel, marketed by the Manganese Steel Forge Company, contains 11 to 14 per cent of manganese and 1 to 1.4 carbon, and has a tensile strength of 160,000 lb. per sq. in. and elongation up to 50 per cent. Amsco steel, of the American Manganese Steel Company, contains 12 to 13 per cent of manganese and 1.2 carbon. The tensile strength is 125,000 lb. per sq. in., and it will work-harden to 500 Brinell. Tisco steel, of the Taylor-Wharton Iron & Steel Company, has up to 15 per cent of manganese, and is used for rails and cross-

overs where high resistance to abrasion is needed. Timang, of this company, is a high-manganese steel made in the form of wire for rock screens. A German stainless-type of steel, made without nickel, has 12 per cent of manganese. It is called Roneusil steel. High-manganese steels are brittle when cast and must be heat-treated. For castings of thin sections or irregular shapes where the drastic water quenching might cause distortion, nickel up to 5 per cent may be added. The Manganese-nickel steels have approximately the same characteristics as the straight manganese steels. Nickel is also used in high-manganese steel wire, and the hard drawn wire has strengths up to 300,000 lb. per sq. in.

Structural steels with 0.50 per cent of carbon and from 1 to 2 of manganese have tensile strength above 90,000 lb. per sq. in. Martinel steel, or Martin elastic limit steel, of Alfred Holt & Company, was an early English steel of this type. D-steel, developed by the British Admiralty for warship construction, contains 1.1 to 1.4 per cent of manganese, 0.33 carbon, and 0.12 silicon. The tensile strength is 96,000 lb. per sq. in. and elongation 17 per cent. N.Y. Central rails have 1.30 to 1.60 manganese and 0.65 carbon. Steels containing 1.30 to 1.90 manganese are now being used in automobile manufacture to replace more expensive alloy steels. Most mills now list these steels as Special alloy machinery steels; those containing about 0.10 per cent of sulphur are designated as Manganese screw stock. The S.A.E. steels X1330 and X1340 are of this type. Intermediate manganese steels are also sold under trade names such as Hylastic, of the American Steel Foundries. Max-El No. 4, of the Crucible Steel Company, is a pearlitic manganese steel with a small amount of chromium and 0.75 carbon, used for spring collets and called Collet steel. Slight amounts of chromium will increase the strength and hardness of the intermediate manganese steels. A forging steel for shafts and crank pins, designated as Manganese-vanadium steel, contains 1.5 to 1.75 per cent of manganese, 0.15 vanadium, and 0.25 carbon. The strength is 90,000 lb. per sq. in. and elongation 30 per cent. Moloie is the name of a Manganese-molybdenum steel of W. T. Flather, Ltd. Pearlitic Nickel-manganese steel contains 1.25 per cent of man-

ganese and 1.25 nickel. It has high yield point and ductility. A steel used by the Union Pacific Railway for draft yokes has 1.4 per cent of nickel and 1.5 manganese. The strength is 95,000 lb. per sq. in. The German high-tensile steel, ECMo100 has 1 per cent of manganese, 1.25 chromium, 0.25 molybdenum, and 0.20 carbon.

**Manganite.** A minor ore of the metal manganese, found with other manganese minerals and with iron. It occurs in Germany, England, and in the Lake Superior region of the United States. The composition is $Mn_2O_3{\cdot}H_2O$, containing theoretically 62.4 per cent of manganese. It usually occurs in radiating masses, having a specific gravity of 4.3 and a hardness of 4. The color is steel gray to iron black.

**Mangrove.** An extract from the bark of the red mangrove tree, *Rhizophora mangle*, the white mangrove, *Laguncularia racemosa*, and other species of Africa, the East Indies, southern Asia, and tropical America, used for tanning leather. The bark usually contains about 35 per cent of tannin; in the Brazilian mangrove, the leaves contain 24 per cent. The solid extract marketed in blocks contains up to 68 per cent of tannin, although the East African may contain as low as 24 per cent. The liquid extract contains from 25 to 35 per cent tannin. Red mangrove contains a red coloring matter which is objectionable in tanning. It is decolorized with albumen. White mangrove produces a light-colored leather. Mangrove from East Africa is called Mangrove cutch.

**Manila hemp.** A fiber obtained from the leafstalks of the Abaca plant, *Musa textilis*, a tree of the banana family growing in the Philippines. It is employed for rope and cordage and is the strongest of the vegetable fibers. The fibers are also very long, from 4 to 8 ft., and do not stiffen when wet. The best grades are light in weight, soft and lustrous, and white in color. The finest fibers, called Lupis, are used locally for weaving into cloth. The plant grows to a height of 20 to 30 ft., with huge leaves characteristic of the banana. Each successive layer of leaves towards the stalk yields fibers that are lighter in color,

higher in strength, and of finer texture than those outside. Fifteen grades of fiber are designated in the Philippines.

**Manketti oil.** A drying oil used in varnishes, obtained from the seed nuts of the tree *Ricinodendron rautanenii*, native to southwest Africa. The seeds yield up to 60 per cent of oil. Manketti oil is light yellow in color, viscous, and has a pleasant odor and taste. It has about two-thirds of the drying power of linseed oil. The nuts of the tree *R. africanum*, of the French Congo, yield a similar oil, which is superior as a drying oil.

**Maple.** The wood of several varieties of maple trees native to the United States and Canada. These include the Sugar maple, *Acer saccharum*, the Broad-leaved maple, or Oregon maple, *A. macrophyllum*, the Red maple, *A. rubrum*, and the Vine maple, *A. circinnatum*. The wood may be white or yellowish to brownish, and is close-grained and hard. It often has a curly, twisted grain. The weight is about 40 lb. per cu. ft. Maple is used for furniture, cabinetwork, flooring, rollers, measuring rules, shoe heels and lasts, and where a hard, fine-grained wood is needed. Sugar maple has an average specific gravity when kiln-dried of 0.67, compressive strength perpendicular to the grain 2,170 lb. per sq. in., and shearing strength parallel to the grain 1,520 lb. per sq. in.

**Marble.** A compact crystalline limestone used for ornamental building, for large slabs for electric power panels, and for ornaments and statuary. In the broad sense, marble includes any limestone that can be polished, including breccia, onyx, and others. Pure limestone would naturally be white, but marble is usually streaked and variegated in many colors. A typical white Vermont marble slightly mottled with gray is more than 99 per cent pure carbonates with only slight amounts of manganese and aluminum oxides and organic matter. The marble of Carrara, Italy, is the most famous white marble, being of delicate texture and very white. It is also hard and brittle. In the United States, the marbles of Vermont are the most noted and occur in many varieties. The colors are white, gray, light green, dark green, red, black, and mottled. For great variety of beautiful

colors the marbles of southern Uruguay are famous and occur in immense blocks. The weight of marble is about 170 lb. per cu. ft., the specific gravity is 2.72, and the crushing strength 10,000 lb. per sq. in. It will ordinarily withstand heat up to 1200°F. without injury. Translucent marble is selected and processed marble, semitransparent to light.

**Marblewood.** A variety of ebony which comes from the tree *Diospyros kurzii*, of India, employed where a hard, close-grained fancy wood is required. It is also called Andaman marblewood, when it comes from the Andaman Islands. The wood is black with yellowish stripes. It has a close, hard, firm texture, will take a fine polish, and weighs 65 lb. per cu. ft.

**Martonite.** A lachrymatory poison used in chemical warfare, made by adding bromine and sulphuric acid to acetone. It is a mixture of 4 molecules of bromoacetone with 1 molecule of chloroacetone, or about 80 per cent of the former and about 20 per cent of the latter. Martonite is a colorless liquid, which is thrown in high-explosive shells and disseminated as a mist. Chloroacetone, or Tonite, is a clear liquid of the composition $CH_3COCH_2Cl$, which vaporizes at 119° C. Bretonite is Iodoacetone, $CH_3COCH_2I$, a brownish liquid boiling at 102°C.

**Mastic.** The gum exudation of the tree *Pistacia lentiscus*, native to the Mediterranean countries. It is used in lacquers, varnishes, and adhesives. Mastic is obtained by making an incision in the tree, each tree yielding 6 to 11 lb. annually. There are two general grades, the purer resin adhering to the tree, and the resin collecting on the ground. It is easily soluble in turpentine but is more expensive than many other natural resins, and is used for high-grade pale varnishes for art work. The name mastic is also erroneously applied to asphalt when used in caulking or adhesive compounds.

**Mauritius hemp.** The fiber obtained from the fleshy leaves of the plant *Furcraea gigantea*, of Mauritius, used for rope and cordage. The plant belongs to the lily family; similar fibers are obtained from other species, notably *F. foetida*, of Brazil.

and *F. cabuya*, of Central America. The latter was the ancient cordage fiber of the Mayas. See Hemp.

**Mayari iron.** The name given to iron made from Cuban ores. These ores contain small percentages of vanadium and titanium, and castings made from the iron have great strength and resistance to wear. They are considered especially suitable for sugar-mill rolls or highgrade machine castings. Mayari pig, as marketed by the Bethlehem Steel Company, contains 1.60 to 2.50 per cent of chromium, 0.80 to 1.25 nickel, 0.25 to 2.25 silicon, 0.10 to 0.20 titanium, 0.05 to 0.08 vanadium, 3.80 to 4.50 total carbon, 0.60 to 2 manganese, under 0.05 sulphur, and under 0.10 phosphorus. Nikrofer is a name used in Germany for pig iron from Greek ore similar in composition.

**Meerschaum.** A soft, white or gray, claylike mineral of the composition $3SiO_2 \cdot 2MgO \cdot 2H_2O$, used for making pipes and cigar holders, but also employed for making various other articles, as it can be cut easily when wet and will withstand heat. When fresh the mineral absorbs grease and makes a lather. It is used as a filler in soaps in Germany. The hardness is about 2 and the specific gravity 1.28. Most of the commercial meerschaum comes from Asia Minor; the mines at Eskisehir have been worked for 20 centuries. A little is produced in New Mexico and some in Spain. Artificial meerschaum is made from meerschaum shavings, kieselguhr, and from silicates of aluminum, calcium, and magnesium.

**Menhaden oil.** An oil obtained by steaming or boiling the fish *Alosa menhaden*, caught along the North Atlantic Coast of America. It was first called Porgy oil, the Maine name for the fish. The fish yield up to 15 per cent of oil, which is used as a substitute or adulterant for linseed oil, for dressing leather, mixing in cutting oils, and for making blown oils. The residue Fish meal is sold for fertilizer. The better qualities of the oil are bleached with fuller's earth. Inferior qualities are obtained by pressure from the residue or may be from putrid fish. Menhaden oil contains about 23 per cent of palmitic acid; the drying power is good, though it does not form an elastic film as do the

vegetable oils. Its strong odor is due to Clupanodonic acid, $C_{17}H_{27}COOH$. The specific gravity is 0.927 to 0.933 and iodine value 180.

**Mercerized cotton.** Cotton yarns treated with sodium hydroxide. The treatment gives a fine, silky luster to the yarn, makes it stronger, and practically nonshrinking. It was discovered in 1851 by John Mercer of Lancashire. The present process consists in immersing the yarns in a stretched condition in the soda, and after washing, neutralizing the remaining alkali with dilute sulphuric acid. The stretching of the yarns prevents excessive shrinking. Mercerized cotton has a greater affinity for dyes than untreated cotton. Mercerized yarns have a variety of uses and, when mixed with silk, cannot be detected easily by ordinary observation.

**Merchant bar iron.** Wrought iron in the form of merchantable bars or rods made by shearing the first muck bars from the bloom into short lengths of 2 to 3 ft., tying 5 or 7 together, faggoting, and hot-rolling or forging. Merchant bar iron is produced in flats, squares, or rounds. Double-refined iron is merchant bar that has been recut, faggoted, and rerolled. Merchant bar iron has an average tensile strength of 50,000 lb. per sq. in. and elongation of about 25 per cent. It is used for rivets, staybolts, general blacksmith forging, and as Reinforcing bars for concrete.

**Mercury.** Also called Quicksilver. A metallic element, symbol Hg. It is the only metal that is a liquid at ordinary temperatures. Mercury has a silvery-white color and a high luster. Its specific gravity is 13.596. The solidifying point is −40°F., and its boiling point is 662°F. It does not oxidize at ordinary temperatures, but when heated to near its boiling point it absorbs oxygen and is converted into a red crystalline powder, Mercuric oxide, HgO, used as a pigment in marine paints. Mercury is derived chiefly from the mineral cinnabar. Spain, Italy, Russia, Mexico, and Western United States are the chief producers. The metal is marketed in steel flasks holding 75 lb. European flasks hold 76 lb. It is used for separating gold and

silver from their ores, for coating mirrors, as an expansive metal in thermometers, in mercury-vapor lamps as well as rectifiers, mercury-vapor motors, and in amalgams with other metals. See Amalgams. Mercury compounds are poisonous, and some are explosive. They are used for insecticides and explosives.

**Mercury fulminate.** A gray or brown sandy powder of the composition $Hg(CNO)_2$, which is the basis of most detonating compositions used for high explosives. Mercury fulminate is made by the action of nitric acid on mercury and alcohol, and is ten times more sensitive than picric acid. It is frequently mixed with potassium chlorite and antimony sulphide for percussion caps. The requisites of a Detonator are that it be ignited easily and reach a maximum rate of detonation quickly. The salt known as Lead azide, $PbN_6$, is sometimes substituted for mercury fulminate. It is much more explosive, and in large crystals is subject to spontaneous explosion; it is now precipitated to suppress crystal formation and give a free-flowing powder not so sensitive to handling. See also Azoimide.

**Mercus pine.** The wood of the tropical pine tree, *Pinus merkusii*, of the East Indies, and cultivated on plantations in north Sumatra. It is called Tinyu pine in British India, and Mindoro pine in the Philippines. It is a valuable construction timber, but the tree is more prized because of the superior quality of the turpentine it yields.

**Mesothorium.** A radioactive substance found in the rare-earth minerals. It is separated out of monazite sand and other thorium ores as a by-product of thorium production. Mesothorium is identical in chemical properties with radium, and cannot be separated from radium if mixed with it. A disadvantage of mesothorium, however, is that it decays, decreasing to half value in 5.5 years. The radiations from mesothorium are the same as from radium, $\alpha$, $\beta$, and $\gamma$ rays being sent off. As it decomposes it forms radiothorium, which is identical in chemical properties with thorium but gives off a powerful $\alpha$ radiation. Mesothorium is used in luminous paints. It is a

better activator than radium for this purpose, but is scarcer and more expensive.

**Metallic soap.** A term used to designate compounds of the fatty acids of the vegetable and animal oils with metals other than the alkali metals. It distinguishes the water-insoluble soaps from the soluble soaps made with potash or soda. Metallic soaps are made by heating a fatty acid in the presence of a metallic oxide or carbonate, and are used in lacquers, leather and textiles, paints, inks, ceramics, and grease. They have the properties of being driers, thickening agents, and flattening agents. They are characterized by their ability to gel in solvents and oils, and by their catalytic action in speeding the oxidation of vegetable oils. When made with fatty acids having high iodine values, the metallic soaps are liquid, such as the oleates and linoleates, but the resinates and tungstates are unstable powders. The stearates are fine, very stable powders. The fatty acid determines the physical properties, but the metal determines the chemical properties. Aluminum stearate is the most widely used metallic soap for colloid products. The resinates, linoleates, and naphthanates are used as driers, the lead, cobalt, and manganese being the most common. Soaps of copper, arsenic, and mercury are used in Antifouling marine paints.

**Metallized wood.** Wood treated with molten metal so that the cells of the wood are filled with the metal. The fusible alloys, with melting points below the scorching point of wood, are used. The wood is immersed in molten metal in a closed container, and air pressure applied. Only a short treatment is needed to impregnate the wood; it can be controlled to give various degrees of penetration. The tensile strength of the wood is not affected, but the hardness, compressive strength, and resistance to flexure are increased. The wood also becomes an electrical conductor lengthwise of the grain. Metallized wood is expensive and is used only where the special characteristics are required.

**Methane.** Also known as Marsh gas, and in coal mines as Fire damp. A colorless, odorless gas of the composition $CH_4$, employed for carbonizing steel. Methane occurs naturally from

the decomposition of plant and animal life, but is produced synthetically by the direct union of carbon or carbon monoxide with hydrogen. It is also produced by the action of water on Aluminum carbide, a gray, massive substance of the composition $Al_4C_3$. Methane has a specific gravity of 0.560 and, since it is much lighter than air, it is easily diffused in air. In air the gas is highly explosive, although the gas alone is not explosive.

**Methyl alcohol.** Commonly known as Wood alcohol, and called Methanol when made synthetically. A colorless, poisonous liquid of the composition $CH_3OH$, obtained from the distillation of hard woods. It is used as a solvent in lacquers, varnishes, and shellac. On oxidation it yields formaldehyde, and is used in making the latter product for synthetic molding materials. The specific gravity of methyl alcohol is 0.795, the solidifying point is −98°C., and the boiling point is 65°C.

**Methyl chloride.** A compound with the composition $CH_3Cl$, which at ordinary temperatures is a gas, but can be liquefied by compression. It is employed in refrigerators as a refrigerant. It is a colorless sweet-smelling gas which is inflammable; a disadvantage is that there is no simple test for leaks. The condensing pressure used is 80.8 lb. gage at 86°F., and the pressure of vaporization used is 6.2 lb. gage at 5°F.

**Mica.** Known originally as Muscovy glass. A group of minerals with monoclinic crystals which break off easily into thin, tough scales, varying from colorless to black. Moscovite is the common variety of mica, and is called Potash mica, or Potash silicate, $H_2KAl_3(SiO_4)_3$. The Magnesium mica known as Phlogopite, of the composition $H_2KMgSi(SiO_4)_3$, is distinguished from moscovite by its decomposition in sulphuric acid. It is known as Amber mica and is superior to moscovite in heat resistance. It comes from Canada and Madagascar. The colorless moscovite used for doors in stoves was called isinglass for this purpose. But the chief use of mica is as an electrical insulator, a heat insulator, and as a filler in plastics and insulating materials. The value of sheet mica depends greatly upon the absence of staining, especially from iron inclusions which decrease the

electric insulating value. Most stains are black, which are from magnetite or other iron oxide. Reddish stains are usually red iron oxide. The brown-colored micas containing much iron are valueless as electric insulators.

The specific gravity of mica is 2.7 to 3.1, and the hardness from 2 to 3. India and Argentina are the largest producers of mica. Ruby mica is the finest grade of Indian mica for electrical condenser use. Mica is marketed as cut or uncut block, sheet, splittings, and ground. The value is usually on the size of clear flat sheets. The sheets vary from clear to black stained in six grades. Splittings are usually only 0.001 in. in thickness, and only 1 or 2 in. in diameter, but are readily cemented together for use. Indian mica has been obtained in "books" as large as 15 ft., and sheets as large as 24 by 30 in. without flaws. Small pieces are made into Ground mica for use as filler in paints, roll roofing, and asphalt shingles. Mica in paints helps to bond the film and prevent cracking, acting similarly to aluminum leaf. Micronized mica is a powder of a fineness of 400 to 1,000 mesh, used as a filler. Micanite is a trade name for small splittings molded together with shellac or resins for insulating use. Mycalex, of the General Electric Company, is an insulating material composed of ground mica and lead borate heated together to the softening point of the borate, 675°C., and compressed while plastic. Part of the mica combines to form a lead boro-silicate giving greater insolubility. Mycalex has good mechanical strength and is a good heat and electrical insulator. Lamicoid is a Bakelite resin with mica filler produced by the Mica Insulator Company. Micabond is a trade name of the Continental-Diamond Fiber Company for mica bonded with shellac and resin to form sheets, tubes, and molded parts. Micabond cloth is mica splittings faced on one side with tissue and on the other with cotton cloth. Watsonite is the name of a mica substitute invented by Charles E. Watson, consisting of scrap or flake mica dehydrated by heating and then sheeted with a flexible binder. A Synthetic mica, known as Alsifilm, developed by Dr. E. A. Hauser, is produced from bentonite, and is made in thin, transparent sheets with many of the characteristics of mica. Much fine powdered mica for use as filler is obtained as a by-product in the washing

of kaolin, and also mica flake produced from pegmatic deposits is used in the manufacture of shingles and roofing.

**Millerite.** A minor ore of the metal nickel, occurring in Europe and in various parts of the United States. It is a nickel sulphide, NiS, containing theoretically 64.7 per cent of nickel. It is usually found in radiating groups of slender crystals, with specific gravity 5.65 and hardness 3.5. It has a pale-yellow color, and a metallic luster.

**Millstone.** Any stone employed for grinding paint, cement, grain, or minerals. Millstones are made from sandstone, basalt, granite, or quartz conglomerate. Burrstone is a millstone made from chalcedony silica of cellular texture, usually yellowish in color. The stone is also used as a building stone. Esopus stone is a conglomerate of this type from Ulster County, New York. Millstones vary greatly in sharpness of grain and size of grain, but should be of even texture throughout. Chaser stones are very large stones run on edge in mills for grinding minerals.

**Mineral wool.** A fibrous material employed as a heat insulator in walls or as a sound insulator. It was first obtained as a natural product from volcanic craters in Hawaii and was known as Pele's hair. It is made by mixing stone with molten slag from blast furnaces and blowing steam through it. Slag wool is made from slag without the rock. Mineral wool usually consists of a mass of fine, pliant, vitreous fibers, which are incombustible and a nonconductor of heat. Rock wool is made by blowing molten rock in the same manner, and is more uniform than common mineral wool, with physical qualities depending, however, on the class of rock used. The rock wool marketed by Johns-Manville under the name of Banrock is made from high-silica limestone and is used for insulating oven walls for temperatures up to 1000°F. Zerofil is a nonsweating, low-temperature insulating material of the same company consisting of rock wool coated with asphalt. The rock wool of the Philip Carey Company, known as Rocktex, has a heat conductivity of 0.22 B.t.u. per hr. per sq. ft. per deg. F. difference in temperature. Rock cork is a name for a low-temperature insulating material made of rock

wool molded in sheet form with a waterproof binder, used for walls in cold-storage rooms. Rock wool is marketed as loose wool, of fine silky fibers, in granulated pellets, and in bats or matted pads. Rock wool quilt consists of felted fibers stitched between layers of treated kraft paper. Selected mineral, to give various characteristics, may be used to make mineral wools. Wollastonite, a natural Calcium meta-silicate, $CaSiO_3$, found in California, is melted to produce a mineral wool.

**Misch metal.** A natural mixture of the metals cerium, lanthanum, and didymium, used as a pyrophoric alloy in cigarette lighters. The waste matter from monazite sand after the extraction of the thorium oxide may contain large quantities of cerium oxide, and the rare-earth metals lanthanum and didymium, yttrium, and other substances. This is reduced to the metallic state by converting the oxides to chlorides and then removing the metal by electrolysis. The material obtained is an alloy containing 50 per cent cerium and 45 per cent lanthanum and didymium. It is called Misch metal, the German name for mixed metal. It is employed in making the pyrophoric alloy known as Auer metal. Another use is for removing gases from radio tubes. See also Kunheim metal.

**Mixed acid.** A name used in the nitrocellulose and dyestuffs industries for any mixture of nitric and sulphuric acids. Standard mixed acid contains 36 per cent of nitric, and the remainder sulphuric. Mixed acid is used chiefly in the preparation of pyroxylin and nitrocellulose.

**Modified aluminum alloys.** High-silicon aluminum alloys modified by adding sodium, sodium hydroxide, or an alkaline chloride to the melt, thus refining the grain and increasing the strength and ductility. The process was developed in Europe and was covered by various patents. Alcoa 47, of the Aluminum Company of America, is a 13 per cent silicon modified alloy of high strength; the modified alloys are not used extensively in the United States, the alloys containing copper being used where increased strength is required. See LoEx alloy. Alpax, invented originally by Aladar Pacz and produced by Lightalloys, Ltd.,

contains 8 to 13 per cent silicon, with the remainder aluminum. This alloy is treated with sodium during the casting. Small amounts of magnesium, up to 0.50 per cent, may be included in the modified alloys to give heat-treating properties and increase the strength and hardness, but the addition of any copper decreases the corrosion resistance. The alloys are noted for being the lightest of all the aluminum alloys, having a specific gravity of about 2.68. They also have higher thermal conductivity than many of the other aluminum alloys, which makes them suitable for such uses as engine pistons and cylinders. A 13 per cent silicon-aluminum alloy normally has a tensile strength of about 24,000 lb. per sq. in. with elongation of only 5 per cent, but by modification and heat treatment it will have a tensile strength of 32,000 lb. per sq. in., elongation of 10 per cent, and Brinell hardness of about 60. The modification also gives a fine, dense grain. The modified alloys are known in Germany as Silumin. English alloys of this class are Wilmil, of William Mills, Ltd.; Birmasil, of the Birmingham Aluminum Casting Company, Ltd.; and M.V.C. aluminum alloy, of Metropolitan-Vickers. Italsil is the name of an Italian modified alloy. Telectal is a German low-silicon aluminum alloy modified with lithium.

**Mohair.** The long, lustrous fleece of the Angora goat, important as a textile fiber because of its luster, length, strength, and spinning qualities. Mohair fabrics are used for upholstery material for hard service, and valued for summer wearing apparel and for plushes. Mohair commonly contains shorter fibers, coarse and difficult to dye. These are known as Kemp and sometimes comprise 18 per cent of the fiber. They are removed by combing. Mohair has a natural curl but no crimp, and does not felt like wool. The American fiber is 6 to 8 in. long, and the Turkish fiber is up to 10 in. long.

**Molding sand.** Called also Foundry sand. Any sand employed for making molds for casting metals, but especially referring to sands that are refractory and have also binding qualities. Pure silica is ideal for heat resistance, but must contain enough alumina to make it bind together. Molding sands may contain from 80 to 92 per cent of silica, up to about 15 per cent of alumina,

about 2 per cent of iron oxide, and not more than a trace of lime. Some molding sand contains enough clay or loam to bond it when tamped into place. The amount of bond in Grant and in Tuscarawa sand is 17 to 18 per cent. About 33 per cent of these natural sands pass through a No. 100 screen, and 20 through a 150 screen. The finer the grain, the smoother the casting, but fine-grained sand is not suitable for heavy work because of its impermeability to the gases. Sands without natural bond are more refractory and are used for steel molding. Sands for steel casting must contain over 90 per cent of silica, preferably 98 per cent, and are mixed with 6 to 10 per cent of fireclay. These are usually called Silica sands as distinct from foundry or molding sands. Zircon sand has high heat resistance, and is used for alloy steel casting. Zircon flour is used as a mold wash. See also Olivine.

Molding sands may contain from 5 to 18 per cent of clay substances; the silica sands do not. About 25 per cent of a medium molding sand will be retained on a 150-mesh sieve, and about 10 per cent on a 200-mesh sieve. Sand with rounded grains is preferred, and the grains must be very uniform in size to prevent "filling." When molding sand is "burned out," it is made suitable for re-use by adding bond but, when fireclay is used as a bond, it adheres to the sand grains and makes it unsuitable for re-use. Parting sand is a round-grained sand without bond used on the joints of molds. Foundry parting is usually tripoli or bentonite. Cores are made with sand mixed with core oils. Green-sand cores are unbaked cores made with molding sand.

**Molybdenum.** A silvery white metal, symbol Mo, occurring chiefly in the mineral molybdenite but also obtained as a by-product from copper ores. About 90 per cent of all molybdenum is produced in the United States. The metal has a specific gravity of 10.2 and melting point of 4750°F. It is ductile, softer than tungsten, and is readily worked or drawn into very fine wire. The tensile strength of rolled molybdenum is 260,000 lb. per sq. in. and Brinell hardness 147. Because of the high melting point, the extraction of the metal is similar to that of tungsten. The commercial metal is 99.95 per cent pure. It is used for grids,

hooks, and support members in radio and light bulbs, for windings in electric furnaces, welding electrodes, and as an alloying element in steels and special alloys. The pure metal is marketed in rods up to 3/4 in. in diameter, in sheets as thin as 0.001 in., and in wire as fine as 0.004 in.

**Molybdenum cast iron.** Cast iron containing small amounts of molybdenum added to the iron as ferromolybdenum or as calcium molybdate. Molybdenum in iron is not a carbide-former or a graphitizer. It goes into direct solid solution and refines the matrix, increasing the strength, toughness, and wear resistance. Usually the manganese is increased when molybdenum is added, and the irons are more uniform in structure than plain cast iron. A plain molybdenum cast iron with 0.65 per cent of molybdenum has a tensile strength of 44,000 lb. per sq. in. and Brinell hardness of 223, which can be raised by heat treatment to above 60,000 lb. per sq. in. with a hardness above 300 Brinell. Greater hardness can be obtained in the iron with the addition of small amounts of chromium. A Chrome-molybdenum cast iron with 0.50 chromium, 0.50 molybdenum, and 1.25 per cent of manganese added to the cupola, resulting in an iron of 3.1 total carbon, 0.30 molybdenum, 0.33 chromium, and 0.75 manganese, has a tensile strength of 48,000 lb. per sq. in., Brinell hardness of 240, and an increase of about 40 per cent in transverse strength over the plain iron. Raising the amount of molybdenum increases the hardness, but the machinability is kept by the addition of nickel or copper. Nickel-molybdenum cast irons have hardnesses as high as 300 Brinell without massive carbides that interfere with machining. An iron with 0.80 per cent each of molybdenum and nickel, without chromium, has a tensile strength of 50,000 lb. per sq. in. and a hardness of 270 Brinell. It has great uniformity, and can be cast in combined thin and heavy sections.

**Molybdenum ores.** Molybdenite is the chief ore of the metal molybdenum. It is a molybdenum disulphide, $MoS_2$, containing 60 per cent of molybdenum, occurring in granite, gneiss, and granular limestone. Molybdenite resembles graphite in appearance, with a lead-gray color, metallic luster and greasy feel. The hardness is 1, and the specific gravity is 4.75. It is infusible.

The American production of molybdenite is from Colorado, New Mexico, and Nevada. Wulfenite, another important ore, is a Lead molybdate, $PbMoO_4$, and occurs in lead veins with other ores of lead. It is found in Utah, Nevada, Arizona, and New Mexico. Wulfenite occurs in crystals and also massive granular. The specific gravity is 6.7 and hardness 3. Its color is yellow, orange, gray, red, or white. Molybdite, another ore, is a hydrous ferric molybdate of the composition $Fe_2O_3 \cdot 3MoO_3 \cdot 7H_2O$. It occurs either crystalline massive or as an earthy powder. It is yellowish, with a specific gravity of 4.5 and a hardness of about 1.5. Molybdenum ores are converted into ferromolybdenum or into calcium molybdate for use in adding molybdenum to steel. Briquettes of Molybdic oxide, containing 70 to 75 per cent of molybdenum trioxide and 12 per cent of carbon, are also marketed for alloying steel.

**Molybdenum steel.** Next to carbon, molybdenum is the most effective hardening element for steel. It also has the property like tungsten of giving steel the quality of red hardness, requiring a smaller amount for the same effect. It is also used in hot-work steels, and to replace part of the tungsten in high-speed steels. See High-speed steel and Hot-work steel. It is added to heat-resistant irons and steels to make them resistant to deformation at high temperatures and to "creep" at moderate temperatures. Molybdenum in small amounts also increases the elastic limit of steel, reduces the grain size, and strengthens the crystalline structure. It goes into solid solution, but when other elements are present it may form carbides and harden the steel, giving greater wear resistance. It also widens the heat-treating range in tool steels. As it decreases the temper brittleness, small amounts are added to nitriding steels. Plain Carbon-molybdenum steels are easier to machine than other steels of equal hardness. Molybdenum structural steels usually have from 0.20 to 0.75 per cent of molybdenum. S.A.E. steels 4130 and 4140 contain about 1 per cent of chromium and 0.20 molybdenum, and are high-strength forging steels for such uses as connecting rods. Allenoy, used by the Allen Mfg. Company for hollow-head screws, is S.A.E. 4150 steel. S.A.E. steels 4615 to 4650 have no chromium

but contain about 1.75 per cent of nickel. S.A.E. 4650 Nickel-molybdenum steel is used for forming dies and, when hardened and drawn to a hardness of 435 Brinell, has a tensile strength of 215,000 lb. per sq. in. Hyten M steel, of Wheelock, Lovejoy & Company, and Durodi steel, of A. Finkl & Sons, are high-strength nickel-chromium-molybdenum steels. Up to 3 per cent of molybdenum is used in stainless steels for cast parts for hot oil and chemical equipment. Lebanon 22-XM steel has 19.5 per cent of chromium, 9 nickel, and 3 molybdenum. Welmet, of the Welland Electric Steel Foundry, is a steel of this type.

The old Damascus steel and Toledo steel were molybdenum steels, the molybdenum being in the original ore. Damascene steel is a name referring to the wavy marks made on blades by forging and was not necessarily a molybdenum steel. But the original Wootz steel, or Indian steel, of this type, contained small percentages of aluminum incorporated in some accidental manner. Wootz steel was made in the crucible, although the crucible method was not used in Europe until 1740.

**Monazite.** A mineral occurring as sand or in granular masses. It is the chief source of thorium oxide for gas mantles and of the rare-earth metals. Most of the supply comes from sea sand of Brazil and India. It is a phosphate of the cerium metals $(CeLaY)PO_4$, with Thorium silicate, $ThSiO_4$, having a specific gravity of 5.2 and hardness of 5.5. It has a reddish-brown color with a resinous luster. See Thoria.

**Monel metal.** A natural alloy produced directly from Canadian bessemer matte by reducing the nickel ore. It was introduced in 1905 by the International Nickel Company. The average composition is: nickel, 67 per cent; copper, 28 per cent; iron, manganese, silicon, and other elements, 5 per cent. The alloy may be cast, rolled, or forged, and can be annealed after cold-working. It is resistant to corrosion and to the action of many acids, and will retain its bright nickel-white surface under ordinary conditions. The melting point is about 2460°F. and weight 0.318 lb. per cu. in. The tensile strength is 65,000 lb. per sq. in., with elongation up to 50 per cent depending upon the condition of hard rolling. The cast metal may have a tensile

strength up to 100,000 lb. per sq. in. Monel metal is employed for parts for chemical and mining equipment, marine fittings, kitchen and restaurant equipment, and valves. A synthetic alloy of this type is Mond metal, of the American Nickel Corporation. It contains higher manganese; the approximate composition is 70 per cent of nickel, 26 copper, and 4 manganese.

S Monel is an alloy of Monel metal with 3.75 per cent of silicon. It is used for valves and for castings subject to wear and corrosion. It has a hardness of 275 to 390 Brinell when heat-treated. K Monel is an alloy of Monel metal with a small amount of aluminum. It can be hardened by heat-treatment. A typical composition is: 63.3 per cent nickel, 30.8 copper, 3.5 aluminum, 1.5 iron, 0.5 manganese, with small amounts of carbon, sulphur, and silicon. The soft alloy, with a hardness of 145 Brinell, will have a hardness above 300 Brinell when heat-treated, and a tensile strength up to 160,000 lb. per sq. in. It will retain its hardness up to 700°F. and is suitable for high-pressure steam valves. Ebonized Monel is Monel metal in commercial form with a lustrous ebony finish obtained by an oxidizing process.

**Mordant.** A substance used in dyeing for fixing the color. A mordant must have an affinity for the material being dyed, and at the same time the property of combining with the dyestuff. The vegetable fibers, such as cotton and linen, frequently require mordants. The mordant may be applied first, usually in a hot solution or simultaneously with the dye. Besides fixing the color, mordants sometimes also increase the brilliancy of the dye. A common mordant is alum. Salts of aluminum, chromium, and other metals are used. In gilding, the term mordant is used to mean a viscous or sticky substance employed to make the gold leaf adhere, but such a material does not have the chemical action of a mordant.

**Mosaic gold.** Also called Artificial gold. A name given in the paint industry to Stannic sulphide, $SnS_2$, a yellow amorphous powder used in gilding and bronzing paints. It is made by the interaction of tin, sulphur, and ammonium chloride. The name Mosaic gold is also applied to the high-copper brasses used for cheap jewelry.

**Mossy zinc.** A disintegrated metallic zinc produced by pouring the molten metal into water. It is used in the making of face brick to obtain various color effects. The grade known as Feathered zinc is of a small grain size, all of it passing through a ¼-in. screen, and 10 per cent through an 80-mesh screen.

**Mother of pearl.** The hard, brilliant-colored internal layer of the pearl oyster shell and of certain other marine shell fish. It is employed for knife handles, buttons, and other articles. Large oysters of the Indian Ocean, especially off Ceylon and in the Persian Gulf, furnish the best mother of pearl. The iridescent appearance is due to the structure of the nacre coating. Mother of pearl is brittle but can be worked with steel saws and drills using a weak acid lubricant.

**Mucilage.** A sticky substance obtained from linseed and other seeds, and employed as an adhesive. The seeds are infused in hot water, bruised, and strained. The gummy substance, which contains arabinose, glucose, and galactose, is precipitated, and a heavy solution is known as mucilage. It is easily soluble in water, and is used as a light cementing material for paper.

**Mullite.** A mineral found originally in the Isle of Mull and employed as a refractory material for firebrick and furnace linings. The natural material occurs as fused argillaceous sediment inclusions in the mineral Buchite, but it is rare and is produced artificially. It can be made by decomposing Sillimanite by heating to 1850°C. Artificial mullite, or Synthetic mullite, made by a prolonged fusing in the electric furnace of a mixture of silica sand or diasporic clay and bauxite, has the composition $3Al_2O_3 \cdot 2SiO_2$. It is valued as a refractory because it does not soften below its high melting point, 3290°F., and will withstand continuous temperature changes. Sillimanite, and Andalusite found in California, is a combination of alumina and silica. It is also made by burning silica clay and alumina at a very high temperature. It is used for making spark plugs, chemical crucibles, and extruding dies. For spark-plug cores it is fired at a temperature of 1450°C. and aged before use. The tensile strength is above 9,000 lb. per sq. in., or double that of porcelain, and it

has high dielectric strength. The hardness is 6 to 7 Moh. Sillimanite is decomposed to mullite and silica when heated above 1550°C. Kyanite, found in North Carolina, and Dumortierite, produced in Nevada, are of the same approximate composition as sillimanite but have a different crystallization. A high-grade electric porcelain material marketed by Champion Sillimanite, Inc., under the name of Champion Sillimanite, is a mixture of andalusite and dumortierite. Shamra is the trade name of a mullite refractory produced by the Mullite Refractories Company. Mullfrax is a mullite refractory of the Carborundum Company. A Synthetic mullite made by fusing a mixture of kyanite and alumina is known as Durox and is used for spark-plug porcelains. Kyanite ore from California, containing 35 per cent of kyanite and much quartz, is ground to a powder and used for ceramics.

**Muntz metal.** A yellow brass containing 60 per cent copper and 40 zinc, invented in 1832 by George F. Muntz. In England it is called Yellow metal; it is also known as Malleable brass. It is now a standard product of the brass mills. Muntz metal has a tensile strength, when annealed, of 57,000 lb. per sq. in., elongation 48 per cent, and Brinell hardness of 93. When hard-rolled, the strength is 80,000 lb. per sq. in. and elongation 9 per cent. The weight is 0.303 lb. per cu. in. It is used for sheathing, marine fittings, bolts, and parts exposed to corrosion. Muntz metal is frequently modified with small amounts of iron or manganese or both, for high-strength castings for such things as cylinders and for forgings. See Delta brass. High-strength brass is a 60–40 brass with both iron and manganese. Extruding brass, for extruded shapes and bars, is usually this alloy modified with lead up to 3 per cent. Macht's metal was an early forging brass containing 57 per cent of copper and 43 zinc, with small amounts of other elements. Pin metal, for common pins, has 62 per cent of copper and 38 zinc.

**Mushet steel.** The trade name of a group of English high-speed steels made by Samuel Osborn & Company, Ltd., but previous to the advent of high-speed steel the name in the United States meant self-hardening tool steels containing tung-

sten. Early Mushet steels contained from 5 to 8 per cent of tungsten, up to 2.5 manganese, up to 1.5 silicon, and very high carbon, with sometimes chromium. From the years 1893 to 1898 F. W. Taylor experimented with cutting tools made with a substitution of chromium for the high manganese and with less carbon. A typical Taylor-White steel, marketed about 1900, contained 8 per cent of tungsten, 1.8 chromium, 1.15 carbon, 0.18 manganese, and 0.25 silicon. With these steels it was learned that red hardness was developed by heating close to the melting point, and from them came the high-speed steels.

**Music wire.** A high-grade, uniform steel originally intended for strings for musical instruments, but now employed for the manufacture of spiral springs. It is the highest grade of spring wire and is made of acid open-hearth steel or electric steel, free from slag or dirt and low in sulphur and phosphorus. The carbon content is about 0.80 per cent. The tensile strength, when hard drawn, is from 225,000 to 400,000 lb. per sq. in., but it should be tough enough to bend 180 deg. flat upon itself without cracking, or wind into a close helix with inside diameter 1 to 1½ times the diameter of the wire. The wire 0.187 in. in diameter has an ultimate strength of 230,000 lb. per sq. in.; 0.015 wire has a strength of 400,000 lb. per sq. in. The wire is usually marketed in gage sizes according to the Washburn & Moen and the music-wire gages. Wire below 0.034 in. in diameter (No. 15 gage) is furnished on reels. Larger sizes are in coils. Music wire for springs is from No. 00, which is 0.0085 in. in diameter, to No. 36, which is 0.102 in. See also Piano wire.

**Muslin.** A plain white cotton fabric with a downy nap on the surface. It has a great variety of uses, and industrially is employed for filtering, sacking, and lining. The full-bleached muslin is usually made of finer yarns than the unbleached. In the cheaper grades it is sometimes heavily sized, which disappears on washing. For polishing cloths it should be unsized.

**Mustard gas.** A substance of the composition $(CH_2Cl\text{-}CH_2)_2S$, known chemically as Dichloro-diethyl sulphide, and used as a poison gas in chemical warfare. It is also known by the

English as Blister gas, Yperite, and Yellow cross. It is an oily liquid which boils at 210°C. and vaporizes easily in the air. The specific gravity is 1.2741. Mustard gas irritates the eyes and destroys the cornea, blisters the skin, affects the lungs, and causes discharge from the nose and vomiting. One part in 14 million parts of air is toxic, and is dangerous in dilutions that cannot be detected by smell. The gas has a smell of water cress, but when impure has a faint odor of mustard. In warfare, Gas detectors of aniline dyes or chrome yellow are used, which change color on the presence of the gas in the air. Another powerful vesicant, or blister gas, is the German gas Bromlost, which is Dibromethyl sulphide, $S(CH_2CH_2)_2Br_2$. It is a solid which melts at 21°C. and boils at 250°C. See Poison gases.

**Naphtha.** A light, colorless liquid which distills off from petroleum after the petroleum ether. The specific gravity is from 0.631 to 0.660, or slightly higher, and the term is somewhat indefinite. The very lightest of the distillate, used as a solvent for fats, rubber, and resins, is the same as petroleum ether or benzine; the heaviest distillates approach gasoline and are used for fuel. See Benzine. The name naphtha is also applied to various grades of light oils obtained in the distillation of coal tar. These include Solvent naphtha, having a specific gravity of 0.862 to 0.872, with a boiling point below 160°C., and Heavy naphtha, a dark liquid of specific gravity between 0.925 and 0.950, and boiling point between 160 and 220°C. High flash naphtha is a petroleum fraction with a specific gravity within the range of the gasolines and a boiling point above 150°C. Various trade names are given to the light petroleum distillates used as solvents and in paints and varnishes. Naphtholite, of the Globe Chemical Company, has a specific gravity of 0.737, and an initial boiling point at 102°C. Solvesso, of the Esso Marketers, is a hydrogenated distillate in various grades with specific gravities from 0.797 to 0.937. Grade 1 has a boiling range from 93 to 135°C. Naphthalene, commonly used against moths, and also in making celluloid, is a white solid of the composition $C_{10}H_8$, and is one of the heavy distillates from coal tar. Halowax is the trade name of the Halowax Corporation for nonflammable chlorinated naphtha-

lene used for waterproofing and fireproofing fabrics and cable coverings. Halowax oil is used as a solvent for rubber and resins.

**Naval brass.** Also called Naval bronze. A 60–40 brass modified with a small amount of tin to give greater hardness and corrosion resistance. The usual composition is 60 per cent copper, 39.25 zinc, and 0.75 tin. The Roman bronze of the Revere Copper & Brass Company has this composition. The Naval brass marketed by the American Brass Company under the name of Tobin bronze contains 59 to 61 per cent copper, 0.5 to 1.0 tin, and the balance zinc. It is essentially a wrought metal; in rod form it has a fine grain structure produced by working the metal. The tensile strength of the soft rod is 52,000 lb. per sq. in., and of the hard-drawn bar 67,000 lb. per sq. in. The electrical conductivity is 25 per cent that of copper. It is used for marine fittings, forgings, and die-pressed parts. Federal specifications for naval brass rod call for 0.5 to 1.5 per cent of tin and 0.20 lead. Chamet bronze, of the Chase Brass & Copper Company, is a naval brass of government specifications. Redalloy, of the same company, has higher copper. It contains 85 per cent of copper, 14 zinc, and 1 tin. The tensile strength, annealed, is 42,000 lb. per sq. in. and elongation 48 per cent.

**Neatsfoot oil.** A pale-yellow oil obtained by boiling the feet of cattle or sheep in water, skimming the oil from the surface, and pressing through a filter. The oil is used for leather finishing, and for lubricants. For high-grade cold-test lubricating oil for fine instruments the stearin is pressed out. The specific gravity of neatsfoot oil is 0.916, iodine value 74, and saponification value 197. The oil is noted for its resistance to rancidity.

**Neon.** A rare gas, symbol Ne, which occurs in minute quantities in the atmosphere with helium and argon. It is procured from the air by liquefaction. It is an emitter of light and is used for sign lighting and in glow lamps. The specific gravity, compared with air, is 0.674. It liquefies at −245°C. It is colorless, but gives a reddish-orange glow in lamps to which an electric current is applied. Neon is also used in voltage-regulating tubes for radio apparatus, and will respond to low voltages. In tele-

vision the neon lamp will give fluctuations from full brilliancy to total darkness as many as 100,000 times a second. In the atom of the gas neon there are claimed to be ten negative electrons revolving in regular orbits around one positive nucleus. The ionization, or tearing away of an electron, and the recombination produce the glow.

All colored electric advertising signs are often referred to as "neon" signs, but the colors other than orange are produced by different gases. Argon gives a purple light when an electric current is passed through it. See Argon. Krypton, an elementary gas, occurring in the air to the extent of one part in a million, gives a pale violet light. It liquefies at −152°C. Xenon, another gas occurring in the air to the extent of one part in eleven million, gives a sky-blue to green light. See also Helium.

**Neutral oils.** A trade name for oils obtained by distillation from petroleum without "cracking." Usually, neutral oils are filtered and will not emulsify in contact with water as do paraffin oils. They are thus considered valuable for use for crankcase lubrication and in circulating systems. Treated neutrals are lower in specific gravity then filtered neutrals. All neutral oils are heavier than paraffin oils. They are sometimes "debloomed" by exposing the oils in shallow tanks to weather and bleach.

**New Zealand flax.** A fiber obtained from the leaves of the New Zealand swamp lily, *Phormium tenax*, also grown in Argentina and some other countries. The fibers have great strength. They are white, soft, and lustrous, and are used for cordage. There are two varieties of the plant, one reaching a height of 16 ft. and the other not more than 6 ft. The fibers are obtained by scraping away the woody pulp from the leaves.

**Niccolite.** A minor ore of the metal nickel. It is a nickel-arsenide, NiAs, containing theoretically 43.9 per cent of nickel, usually with a little iron, cobalt, and sulphur. The mineral occurs massive, with a specific gravity of 7.5 and a hardness of 5 to 5.5. The color is pale copper-red with a metallic luster. It is sometimes called copper-nickel because of its color. Niccolite is found in Canada, Germany, and Sweden.

**Nickel.** A silvery-white metal with a yellowish cast first isolated in 1751, but used in alloy with copper since ancient times. Its ores are sulphides, silicates, and arsenides, the most common being the mineral Pyrrholite, or Magnetic pyrites, which is a sulphide of iron of the approximate formula $Fe_{11}S_{12}$, but carrying nickel in sufficient amount to become a valuable ore of nickel. The Sudbury (Ontario) ore contains also copper and is the source of Monel metal. See also Garnierite, Millerite, Niccolite. Nickel has a specific gravity of 8.84, melts at 2646°F., and is magnetic up to 680°F. It is marketed in grains or powder, in electrolytic sheets, blocks, shot, and in malleable forms. The metal is resistant to corrosion and to most acids except nitric. The electrical conductivity is 16 per cent that of copper. The tensile strength of hard rolled sheet is 115,000 lb. per sq. in., elongation 5 per cent, and Rockwell B hardness 100. The tensile strength when annealed is 70,000 lb. per sq. in., elongation 45 per cent, and hardness 60. Nickel is difficult to cast when pure as it absorbs oxygen and also dissolves carbon and sulphur.

Nickel finds its greatest uses in alloys, particularly with copper and steel. See Nickel steel, Nickel-chromium alloys. With copper and zinc it forms German silver. See also Nickel brass. It is also used to make white gold, 15 per cent of nickel changing the color of gold to white. Nickel steels have high strength and resistance. Nickel is also used in coinage alloys and in commercial heat-resistant and corrosion-resistant alloys. More than 85 per cent of the world's nickel production comes from Ontario, Canada, and most of the remainder from the garnierite ores of New Caledonia. The standard A.S.T.M. grades of virgin nickel are Electrolytic, containing 99.5 per cent of nickel; X shot, containing 98.9 per cent; A shot, with 97.75 per cent; and Ingot, with 98.5 per cent. But electrolytic nickel is available 99.95 per cent pure, including not over 0.40 cobalt.

**Nickel alloys.** Any alloy containing nickel as the base metal, or as the chief alloying element. Nickel goes into solution in copper in all proportions and continually raises the melting point of copper alloys. See Cupro-nickel. In brasses and bronzes, nickel is used for the color effect and for toughening

and strengthening the alloys. See Nickel silver and Nickel bronze. Nickel is employed in both ferrous and nonferrous alloys to produce heat-resistant and acid-resistant metals. See Heat-resistant alloys and Resistance wire. Nickel-manganese alloys are used for electric resistance wire. See Magno. These alloys are also used as Cold-resistant alloys in places where steel or iron would be brittle at low temperatures. AMF alloy, for liquid-air valves, is a French alloy containing 55 to 60 per cent of nickel, up to 3 manganese, 0.4 carbon, and the balance iron, which will withstand shocks at low temperatures. See Climax metal. A group of Acid-resistant alloys (see also Silicon iron) is produced with nickel as the base and silicon as the hardener, with sometimes other elements. A group of Acid-resistant alloys marketed by the Burgess-Parr Company under the names of Illium and Parr metal, are complex alloys. A typical analysis of Illium is: nickel, 60.65 per cent; chromium, 21.07; copper, 6.42; molybdenum, 4.67; tungsten, 2.13; silicon, 1.04; aluminum 1.09; manganese, 1; and a small amount of iron. It is a very dense metal and has been used for chemical pump castings. Illium R has a tensile strength of about 100,000 lb. per sq. in. when cold-rolled and annealed, and up to 150,000 lb. per sq. in. with hardness of 365 when cold-rolled and unannealed.

Copper-nickel-iron alloys, used for hardware and plumbing fixtures, are white in color and resistant to acids and corrosion. Aterite, of the Aterite Company, is a group of casting alloys containing 10 to 40 per cent of nickel, 30 to 60 copper, 5 to 10 iron, and sometimes up to 5 per cent of zinc or 2 per cent of lead. Grades for wrought metals contain little iron. Alcumite, of the Duriron Company, is a yellow, copper-base alloy containing nickel, aluminum, iron, and manganese. Hastelloy is the trade name of the Haynes Stellite Company for a group of acid-resistant alloys. Hastelloy A contains 60 per cent nickel, 20 molybdenum, and 20 iron. It has a specific gravity of 8.8, tensile strength, forged, of about 115,000 lb. per sq. in., and Brinell hardness of 97. It casts easily and resists most acids except nitric. Hastelloy C contains chromium and is more resistant to sulphuric acid. Hastelloy D is a casting alloy containing 90 per cent nickel, 3 copper, 1.5 aluminum, and about 5 silicon. It is resistant

to hot acids and has high strength, with Brinell hardness of 360. Strong and wear-resistant cast irons usually contain nickel, such as Cariron and Bryiron of the Fillmore Foundry, Inc., and Diamite of the Weatherly Foundry & Mfg. Company. The former two have about 1.5 per cent of nickel, and the last one 4.5 per cent of nickel with 1.5 chromium. See Nickel cast iron. Many jewelry alloys, for cheap jewelry, contain nickel. An old alloy known as Paris metal and Lutecine, contained 80 per cent copper, 16 nickel, 1 cobalt, 2 tin, and small amounts of iron and zinc. See Jewelry alloys.

**Nickel-aluminum.** A hardener alloy used for adding nickel to aluminum in the foundry. Nickel increases the tensile strength of aluminum alloys and also improves the finish in die-casting alloys. Commercial nickel-aluminum containing 20 per cent of nickel melts at 1418°F.

**Nickel brass.** The alloys that come naturally into this designation are more usually termed Nickel silver or are known under a wide variety of trade names. See Nickel silver. Nickel-silicon brass contains very small percentages of silicon, usually about 0.60 per cent, which forms a nickel silicide, $Ni_2Si$, increasing the strength and giving heat-treating properties. Rolled nickel-silicon brass, containing 30 per cent of zinc, 2.5 nickel, and 0.65 silicon, has a tensile strength of 114,000 lb. per sq. in. Imitation silver, for hardware and fittings, is a nickel brass containing 57 per cent of copper, 25 zinc, 15 nickel, and 3 cobalt. The bluish color of the cobalt neutralizes the yellow cast of the nickel and produces a silver-white alloy. Silvel is a nickel brass containing 67.5 per cent of copper, 16 zinc, and 6.5 nickel, with sometimes a little cobalt. Nickel brass is an alloy used where white color and corrosion resistance are desired.

Seymourite is the trade name of an alloy of 64 per cent copper, 18 nickel, and 18 zinc, produced by the Seymour Manufacturing Company. It has a white color and is corrosion resistant. Nickeline, used by the Yale & Towne Manufacturing Company for hardware, has 58 to 60 per cent copper, 16.5 nickel, 2 tin, and the remainder zinc. It has high-strength, a white color, and casts well. Nickelene is an old name applied to nickel brass of various

compositions, but an alloy patented in 1912 under this name had 55 per cent of copper, 12.5 nickel, 20.5 zinc, 10 lead, and 2 tin. Most of these alloys have good casting qualities, but they do not machine easily unless they contain some lead. Up to 2 per cent of lead does not affect the color and does not decrease the strength greatly. Tuc Tur, of the Tuc Tur Metal Corporation, is a nickel brass containing 15 per cent of nickel and 22 zinc. Sterlite, of the Sterlite Foundry & Mfg. Company, contains 25 per cent nickel and 20 zinc, with small amounts of iron, manganese, silicon, and carbon. A series of corrosion-resistant nickel brasses is marketed by the American Brass Company under the name of Ambrac. Ambrac No. 850 contains 75 per cent of copper, 20 nickel, and 5 zinc. The tensile strength is 50,000 lb. per sq. in., soft, and 110,000 hard drawn. Other alloys contain more nickel.

**Nickel bronze.** A name given to bronzes containing nickel, which usually replaces part of the tin, producing a tough, fine-grained, and corrosion-resistant metal. A common nickel bronze containing 88 per cent of copper, 5 tin, 5 nickel, and 2 zinc, has a tensile strength of 48,000 lb. per sq. in., elongation of 42 per cent, and Brinell hardness of 86 as cast. When heat-treated or age-hardened, the tensile strength is 87,000 lb. per sq. in., elongation 10 per cent, and Brinell hardness 196. Small amounts of lead take away the age-hardening quality of the alloy, and also lower the ductility. But small amounts of nickel added to bearing bronzes increase the resistance to compression and shock without impairing the plasticity. A bearing bronze of this nature, U.S. Navy 46B22, for machinery carrying heavy loads at slow speeds, contains 15 to 20 per cent of lead, 73 to 80 copper, 5 to 7 tin, and 1 nickel. See High-lead bronze.

For decorative bronze parts, nickel is used to give a white color. At least 10 per cent of nickel is needed to give a satisfactory color for this purpose; this amount also gives corrosion resistance to the bronze. Hardware and plumbing fixtures of these alloys do not require plating. Eclipse bronze is a white bronze of Sargent & Company. M-M-M alloy, of Manning, Maxwell & Moore, Inc., used for pressure valves for superheated steam, contains 60 to 65 per cent of nickel, 24 to 27 copper, 9 to 11 tin, and

small amounts of iron, silicon, and manganese. Mercoloy, of the Merco Nordstrom Valve Company, is a white valve bronze containing 60 per cent of copper, 25 nickel, 10 zinc, 1 tin, 2 lead, 2 iron. It has a tensile strength of 44,000 lb. per sq. in., with elongation of 20 per cent.

**Nickel carbonate.** A salt of nickel used for electroplating nickel. Basic nickel carbonate comes in green crystals and has a composition of $2Ni \cdot CO_3 \cdot 3Ni:(OH)_2 \cdot 4H_2O$. It decomposes on heating and is not soluble in water, but is soluble in acids and in solutions of ammonium salts. A nickel salt used for plating nickel on zinc is Nickel chloride, $NiCl_2$. It comes in yellow scales, or in green scales when crystallized with water. The specific gravity is 2.56. It is soluble in water.

**Nickel cast iron.** A high-strength cast iron in which a small amount of nickel has been introduced. Nickel, like silicon, assists the graphite formation and the carbide decomposition, and therefore reduces chill and acts to eliminate hard carbide spots, chilled edges, and mottled areas. About 1 per cent of nickel is equivalent to $\frac{1}{2}$ per cent of silicon, but the effect of nickel is progressive, and does not make the iron brittle like silicon. Nickel in amounts from 0.5 to 10 per cent will progressively harden cast iron. A gray cast iron which would have a Brinell hardness of 174 was raised to 217 by the addition of 0.67 per cent of nickel, and to 269 by 4.59 per cent of nickel. The same iron with 9 per cent of nickel had a Brinell hardness of 350. Since the nickel promotes the formation of graphite in fine crystals, the iron has a high resistance to wear. Tensile strengths up to 65,000 lb. per sq. in. are obtained in these irons. Ni-Tensyliron is the trade name of the International Nickel Company for a nickel cast iron made by a special process consisting of adding to the melt a graphitizer of nickel-silicon to cause partial decomposition of the combined carbon. With 1.75 per cent of nickel this iron has high strength, and hardness up to 320 Brinell.

Nickel obstructs the passage of electric currents in iron, and iron with 5 per cent of nickel is used for resistance grids. High-nickel iron is also nonmagnetic. Most nickel irons contain chromium in small amounts to increase the chilling power and

refine the grain. It also increases the strength and hardness. Chromium prevents the decomposition of the iron silicide, and hardnesses up to 700 Brinell are possible. An iron containing 4 to 4.5 per cent of nickel, 1.25 to 1.75 chromium, and 3 to 3.5 carbon, is marketed by the Taylor-Wharton Iron and Steel under the name of Flintmetal. It has a Brinell hardness of 600. Wear-resistant castings contain about 3 per cent of nickel and 1 chromium. Lectrocast, of the Detroit Gray Iron Foundry, used for automobile body dies, has 2.75 per cent of nickel and 0.70 chromium. Tensloy, of the Ensign Foundry Company, and Novite, of the Novo Engine Company, have about 1.5 per cent of nickel and 0.50 chromium. Mitchalloy A, of the Robert Mitchell Company, Ltd., has 2.5 per cent of nickel and 0.90 chromium.

High nickel-chromium irons are used for pump and compressor parts handling hot liquids and may contain up to 30 per cent of nickel and 5 chromium. Nogroth metal, of the Q. & C. Company, is a heat-resistant nickel-chromium cast iron. Pyrocast is a high-test nickel-chromium cast iron of the Pacific Foundry Company. Niresist, developed by the International Nickel Company, is an alloy cast iron containing Monel metal with also chromium and manganese. A typical analysis range is nickel, 12 to 15 per cent; copper 5 to 7; chromium, 1.25 to 4; manganese, 1 to 1.5; silicon, 1 to 2; and total carbon, 2.75 to 3.1. The tensile strength is 20,000 to 35,000 lb. per sq. in., with a Brinell hardness of 130 to 170. It can be chilled to a hardness of 350 to 400. It has a low coefficient of expansion, 0.0000100 per deg. F., or about the same as the aluminum-silicon alloys used for pistons. Ni-Hard, of the same company, is a chromium-nickel chilled white iron containing 4 to 6 per cent of nickel and 1 to 2.5 chromium. It is tough with a hard case and, when chilled, has a surface hardness up to 700 Brinell. For greater wear resistance it may contain manganese up to 1.5 per cent.

Vanadium in nickel irons adds strength and wear resistance. Vanick is the name of a Nickel-vanadium cast iron of the Malleable Iron Fittings company. Nickel cast irons and Nickel-chromium cast irons are marketed under many trade names, such as Frankite, of the Frank Foundries Corporation, Alco Ni-Iron, of

the American Locomotive Company, Elfur iron, of the Cramp Brass & Iron Foundry, Tylerite, of the W. S. Tyler Company, Domite of the Dominion Wheel & Foundry Company, and Maxtensile, of the Farrel-Birmingham Company. The nickel-chromium cast irons may also contain molybdenum for greater hardness and wear resistance. Ni-Chillite, of the Mackintosh-Hemphill Company, is a nickel-chromium-molybdenum chilled cast iron for heavy rolls. Mocasco iron, of the Motor Casting Company, is a wear-resistant iron capable of being cast into thin sections without chill. Mocasco 30, for cylinders, has 1 to 1.35 nickel, 0.25 to 0.30 chromium, and 0.75 molybdenum. Strenes metal is the name of the Advance Foundry Company for a nickel-chromium-molybdenum cast iron for heavy dies. Durite is a wear-resistant iron of the Birdsboro Steel Foundry & Machine Company. Ironite, of the Kinite Corporation, is a chromium-nickel-vanadium cast iron used for cams, gears, and wear-resistant parts.

**Nickel-chromium alloys.** A group of alloys of nickel and chromium employed as heat-resistant metals, for resistance wires, and as corrosion-resistant metals for chemical machinery. An alloy of 80 per cent nickel and 20 chromium will withstand temperatures up to 2100°F. without oxidation. Chromel A, of the Hoskins Manufacturing Company, has this composition. The resistivity is 650 ohms per cir. mil ft., tensile strength 120,000 lb. per sq. in., and melting point 1420°C. The color, even when the alloys contain considerable iron, is white and will take a brilliant polish. They are therefore valued for food machinery. The high-chromium alloys, with 25 to 30 per cent of chromium and 8 to 20 nickel, with the remainder iron, will withstand sulphur corrosion. The high-nickel alloys, with 60 to 70 per cent of nickel, are ductile and resistant to cracking and are used for furnace parts. X-ite, of the General Alloys Company, contains 37 to 39 per cent of nickel and 17 to 19 chromium. It is used for carburizing boxes. A group of heat-resistant and corrosion-resistant alloys, under the name of Misco alloys, is produced by the Michigan Steel Casting Company. Misco metal contains 35 per cent of nickel and 10 chromium, with the balance iron.

Misco C contains 29 per cent chromium, 9 nickel, 0.55 manganese, 0.60 silicon, and 0.25 carbon. Miscrome is very resistant to nitric acid. It contains 28 per cent chromium with no nickel. Centricast alloys, of this company, are these corrosion-resistant alloys centrifugally cast for cylinders and pipes. A group of heat-resistant and acid-resistant nickel-chromium alloys is produced by the Standard Alloy Company under the name of Standard-alloy. Another group is marketed by the Copper Alloy Foundry Company under the names of Sweetaloy and Cooper alloys. Copper alloy S-16 has 14 to 20 per cent of chromium with 65 nickel; Cooper alloy S-21A is this combination with 3 per cent of molybdenum and 1.5 silicon. Cimet, of the Driver-Harris Company, used for mine pump parts, has 26 per cent of chromium, 10 nickel, and the balance iron. Gridnic alloys, of this company, are nickel-chromium alloys used for radio grids. Nirex, of the same company, has 80 per cent nickel, 14 chromium, and 6 iron. In annealed sheet form it has a tensile strength of 90,000 lb. per sq. in. with elongation of 50 per cent. Chromel No. 502 has 36 per cent of nickel, 20 chromium, and the balance iron. It is used for furnace fixtures, either rolled or cast. Calite is the name of the Calorizing Company for a series of alloys in both high-nickel and high-chromium grades. Inconel, of the International Nickel Company, used for dairy and food equipment, contains 80 per cent nickel, 14 chromium, and 6 iron. The tensile strength, annealed, is 80,000 to 95,000 lb. per sq. in. with elongation of 45 to 55 per cent.

Nickel-chromium-iron alloys, with silicon and other elements forming complex alloys, are employed for acid-resistant and corrosion-resistant castings and wrought metals for high temperatures. Durimet, of the Duriron Company, is marketed in various grades containing 19.5 to 23 per cent of nickel, 18 to 22 chromium, 2.75 to 3.75 silicon, 0.50 to 0.75 manganese, 1 to 1.5 molybdenum, 0.25 to 0.45 copper. Rezistal, of the Crucible Steel Company, is marketed in many grades resistant to heat, acids, and corrosion. They include stainless steels and special composition nickel-chromium alloys. Rezistal 2600, formerly known as Atha's 2600 alloy, contains 22 per cent of nickel, 8 chromium, 1.75 silicon, 1 copper, 0.70 manganese, and 0.25

carbon. It is nonmagnetic, is resistant to acids, and is easily machinable. See Resistance wire and Heat-resistant alloys.

**Nickel-chromium steel.** Steel containing both nickel and chromium, usually in a ratio of 2 to 3 parts of nickel to 1 of chromium. The 2-to-1 ratio gives great toughness, and the nickel and chromium are intended to balance each other in physical effects. The steels are especially suited for large sections which require heat-treatment, because of the deep and uniform hardening power. Hardness and toughness are the characteristic properties of these steels. Nickel-chromium steel containing 1 to 1.5 per cent of nickel, 0.45 to 0.75 per cent of chromium, and 0.38 to 0.80 per cent of manganese, is used throughout the carbon ranges for casehardened parts and for forgings where high tensile strength and great hardness are required. See Simplex steel. Steel with from 3 to 5 per cent of nickel, 1.8 to 2.5 per cent of chromium, and 0.30 to 0.40 per cent of carbon is employed for heavy armor plate, while armor-piercing projectiles are made from steel containing 0.50 per cent of nickel, 2.5 per cent of chromium, and 0.50 per cent of carbon.

Low nickel-chromium steels, but with more carbon, from 0.60 to 0.80 per cent, are used for drop-forging dies and other tools. R.D.S. steel, of the Carpenter Steel Company, is an oil-hardening, tough, tool steel containing 1.75 per cent nickel, 1 chromium, 0.50 manganese, and 0.75 carbon. An industrial steel of this company, Carpenter No. 5–317, contains the same amounts of nickel and chromium, but 0.50 carbon and less manganese. It is oil hardening, and used for gears, shafts, and shock-resisting parts. The tensile strength is up to 295,000 lb. per sq. in. Samson steel, of this company, used for machinery parts for severe service, contains 1.25 per cent of nickel, 0.60 chromium, and various amounts of carbon. The 0.40 carbon steel, when heat-treated, has a tensile strength of 240,000 lb. per sq. in. and Brinell hardness of 440. The hot-rolled steel has a tensile strength of 115,000 lb. per sq. in. and elongation of 18 per cent. Beaver steel, of the Colonial Steel Company, used for water-quenched forging-die blocks, contains 1.5 per cent nickel, 0.75 chromium, 0.60 manganese, and 0.55 carbon. Colona steel, of the same com-

pany, used for oil-quenched forging dies, has the same nickel and chromium content, but somewhat more manganese and carbon. Nikro-Trimmer steel, of this company, used for hot trimming dies, has higher carbon, 0.85 per cent, but only small amounts of nickel and chromium, 0.30 and 0.55 per cent, respectively. Simplex steel, of the Crucible Steel Company of America, used for forgings, has 1.25 per cent of nickel and 0.60 chromium. In the low-carbon, casehardening grades, for gears, it has a tensile strength of 90,000 lb. per sq. in. S.A.E. steel 3330, containing 3.5 per cent of nickel and 1.5 chromium, when oil-tempered, has a tensile strength of 205,000 lb. per sq. in. and elongation of 13 per cent. Quality steel is the trade name of Quality Steels, Ltd., for nickel-chromium steels in various grades.

Nickel-chromium steels may have temper-brittleness, or low impact resistance, when improperly cooled after heat-treatment. A small amount of molybdenum is sometimes added to prevent this brittleness. Encem steel, of W. T. Flather, Ltd., is a molybdenum steel of this type. Miraculoy, of the Sivyer Steel Castings Company, contains 1.25 per cent of nickel, 0.65 chromium, 0.40 molybdenum, and 1.55 manganese. The tensile strength is 115,000 lb. per sq. in., with elongation of 18 per cent and Brinell hardness of 275. Miscoloy No. 60, of the Michigan Steel Casting Company, is another steel of this type. A Coin steel, used by the Italian Government, contains 22 per cent of chromium, 12 nickel, and a small amount of molybdenum.

Low-carbon nickel-chromium steels are water nardening, but those with appreciable amounts of alloying elements require oil quenching. Air-hardening steels contain up to 4.5 per cent of nickel and 1.6 chromium, but are brittle unless tempered in oil to strengths below 200,000 lb. per sq. in. The alloy known as Krupp analysis steel contains 4 per cent of nickel and 1.5 chromium. The steel under the name of Millaloy, used by Doelger & Kirsten, Inc., for heavy shear blades, is of this analysis with 0.40 carbon. Blades hardened to 530 Brinell have an ultimate strength of 312,000 lb. per sq. in. and elongation of 11 per cent. Nikrome is a nickel-chromium steel of Joseph T. Ryerson & Son, Inc. Nikrome M contains 2.25 per cent nickel, 1 chromium, and 0.45 molybdenum, with 0.40 carbon. It is characterized by very

high strength and uniform hardening, and can be machined up to 450 Brinell. H.T.M. Steel, of this company is a 2 per cent nickel steel with chromium and molybdenum. Nykrom is a steel of W. T. Flather, ltd. Ohioloy is a nickel-chromium steel of the Ohio Steel Foundry Company. All of the nickel-chromium steels require special heat treatment to bring out their best qualities, and in general all of them are difficult to machine.

**Nickel-cobalt alloys.** A group of alloys covered by patent, containing 20 to 30 per cent of cobalt and 70 to 80 of nickel. Nickel has a yellowish cast and cobalt has a blue cast; alloys of the two metals are almost pure white in luster and resemble silver. They are expensive, because of the high cost of cobalt, but the two metals are co-deposited in an electroplating bath to form an alloy deposit on iron, steel, or nonferrous metals. The alloy is harder than either nickel or cobalt alone, and is also more corrosion resistant. Another type of nickel-cobalt complex alloy is Konel, developed by the Westinghouse Electric & Manufactur-Company as a heat-resistant and acid-resistant alloy. It contains 73 per cent of nickel, 17.5 cobalt, 6.5 iron, 2.5 titanium, and 0.2 manganese. At a temperature of 600°C. this alloy has a tensile strength of 66,000 lb. per sq. in. At ordinary temperatures the strength is 100,000 lb. per sq. in. It was originally developed for radio tube filaments.

**Nickel copper.** An alloy of nickel and copper employed for adding nickel to nonferrous alloys. A 50–50 nickel copper has a melting point of 2330°F. and dissolves readily. The Copper-nickel master alloy designated in Federal specifications contains 60 per cent of nickel, 33 copper, 3.5 manganese, and may contain up to 3.5 iron. Such an alloy is used for alloying high-strength bronzes. Copper-nickel alloy is also used for special purposes. Thermalloy, of the Electro Alloys Company, used as a temperature-sensitive magnetic metal for magnetic shunts in watt-hour meters, has 66.5 per cent of nickel, 30 copper, and 2 iron. The permeability falls off with increase in temperature and compensates for errors due to temperature changes.

**Nickel-molybdenum iron.** A group of alloys used for high acid resistance. They may contain up to 40 per cent of molyb-

denum, which takes the place of the chromium used in the more common corrosion-resistant alloys. The most usual alloy in this class contains about 20 per cent of iron, 20 molybdenum, 60 nickel, and small amounts of carbon. This alloy is very resistant to hydrochloric and sulphuric acids, but for high general acid resistance the iron content should be below 10 per cent. Iron adds hardness and stiffness to the alloys, but decreases the acid resistance. Manganese improves the workability, but more than 3 per cent decreases the acid resistance. With chromium the alloys are claimed to be almost as resistant to corrosion as the noble metals. One authority gives the best combination for acid resistance as, 60 per cent nickel, 15 chromium, 2.5 to 7 molybdenum, 2 manganese, and the balance iron. All of the alloys cast easily, and the 20–20–60 alloy is readily machinable. It can be hot-rolled into sheet, or cold-rolled. The melting point is 1300°C., and weight is 0.315 lb. per cu. in. The tensile strength, forged, is 118,000 lb. per sq. in. and Brinell hardness 207. This alloy is very resistant to all acids except nitric.

**Nickel-molybdenum steel.** An alloy steel which is most used in compositions of 1.5 per cent of nickel and 0.15 to 0.25 per cent of molybdenum, with varying percentages of carbon up to 0.50 per cent. These steels are characterized by remarkably uniform properties, are readily forged and heat-treated. Molybdenum produces toughness in the steels, and in the casehardened steel gives a very tough core. Roller bearings are made of this class of steel. A steel used by the Ingersoll Steel & Disc Company for hand shovel blades contains an average of 0.45 carbon, 0.50 manganese, 1.35 nickel, and 0.40 molybdenum. When hot-rolled and heat-treated, it has a tensile strength of 240,000 lb. per sq. in. and elongation of 6 per cent. Super-alloy steel, of this company, is S.A.E. 3160. A 5 per cent nickel steel with 0.30 per cent of carbon and 0.60 molybdenum has a tensile strength of 175,000 to 230,000, with elongation of 12 to 22 per cent, depending upon the heat-treatment. Molybdenum is more frequently added to the steels containing also chromium, the molybdenum giving air-hardening properties, reducing distortion, and making them more resistant to oxidation. See Nickel-chromium steel.

**Nickel shot.** An alloy of nickel with iron made up in small pieces which are easily dissolved in the foundry ladle. It is used for adding nickel to cast iron or ferrous alloys. It is possible to add as much as 5 per cent of nickel to gray iron in the ladle. Nickel shot is made in various grades and sold under trade names. It may contain up to 50 per cent of iron. For adding nickel to nonferrous alloys, nickel-copper is used instead of nickel shot.

**Nickel silver.** A name applied in the machine industries to an alloy of copper, nickel, and zinc, which is practically identical with alloys known in the silverware trade as German silver. Packfong, meaning White copper, is an old name for these alloys. The name Liberty silver, applied to the alloys during the World War, is obsolete. The very early nickel silvers contained some silver and were used for silverware. Wessell's silver contained about 2 per cent, and Ruolz silver about 20 per cent. Baudoin alloy, a French metal, contained 72 per cent copper, 16 nickel, 1.8 cobalt, 2.5 silver, and the balance zinc. See German silver.

Nickel silver is made in regular grades of 5 to 30 per cent nickel, with up to 65 per cent copper, and the balance zinc. Nickel whitens brass and makes it harder and more resistant to corrosion, but the alloys are more difficult to cast because of shrinkage and absorption of gases. They are also subject to fire cracking and are more difficult to roll and draw than brass. The most common nickel silver is the 18 per cent nickel alloy with 55 to 65 per cent of copper, and the balance zinc. The higher copper grades are used for parts where there is much fabricating. As a spring material, with 55 per cent of copper, this alloy has a tensile strength of 110,000 lb. per sq. in., and Brinell hardness of 160, when cold-rolled. The 12 per cent alloy is a dense white metal, readily machinable, and much used for plumbing fixtures. Benedict metal, of the American Brass Company, has 12.5 per cent of nickel, with 2 parts of copper to one of zinc. The cast metal has a strength of 35,000 lb. per sq. in. with elongation of 15 per cent. The higher nickel alloys have more permanent white finish for parts subject to corrosion. Ambrac 854, of the American Brass Company, is a wrought metal with 65 per cent of copper, 30 nickel, and 5 zinc. Pope's Island white metal, of this com-

pany, used for jewelry, has 67 per cent copper, 19.75 nickel, and 13.25 per cent of zinc.

For threaded parts and for casting metals, the nickel silvers usually contain some lead for easier machining. Federal specifications for casting metals call for 65 per cent of copper, 20 nickel, 4 tin, 5 lead, and 6 zinc. The White nickel brass, used for automotive cast parts for trim, is a standard 18 per cent nickel alloy with or without lead. Silveroid, an English alloy for this use, is a cupro-nickel without zinc. An English alloy for tableware, under the name of Newloy, contains 35 nickel, 64 copper, and 1 tin. See Nickel brass and Cupro-nickel.

**Nickel steel.** Steel containing nickel as the predominating alloying element. Nickel added to carbon steel increases the ultimate strength, elastic limit, hardness, and toughness. It lowers the critical range of steel, reducing danger of warpage and cracking. The nickel steels are also of finer structure than ordinary steels. When the percentage of nickel is high, the steel is very resistant to corrosion. The percentage of nickel employed usually varies from 1.5 to 5 per cent, with up to 0.80 per cent of manganese. The bulk of nickel steels contain 2 per cent and 3½ per cent of nickel. They are used for armor plate, structural shapes, rails, heavy-duty machine parts, gears, automobile parts, and ordnance.

The standard A.S.T.M. Structural nickel steel used widely for building construction is an open-hearth steel containing not over 3.25 per cent of nickel, 0.45 of carbon, and 0.70 of manganese. This steel has a tensile strength from 85,000 to 100,000 lb. per sq. in. and a minimum elongation of 18 per cent in 2 in. An automobile steel used by one of the largest companies contains 0.10 to 0.20 per cent of carbon, 3.25 to 3.75 of nickel, 0.30 to 0.60 of manganese, and 0.15 to 0.30 of silicon. When heat-treated, it has a tensile strength up to 80,000 lb. per sq. in. and an elongation of 25 to 35 per cent. Forgings for locomotive crank pins containing 2.5 per cent of nickel, 0.27 carbon, and 0.88 manganese, have a tensile strength of 83,000 lb. per sq. in., elongation of 30 per cent, and reduction of area of 62 per cent. A Nickel-vanadium steel, used for high-strength cast parts, contains 1.5 per cent

nickel, 1 manganese, 0.28 carbon, and 0.10 vanadium. The tensile strength is 90,000 lb. per sq. in. and elongation 25 per cent. Univan steel, of the Union Steel Casting Company, for high-strength locomotive castings, is a nickel-vanadium steel of this type. Unionaloy steel, of this company, is an abrasion-resistant steel. See also Nickel-manganese steel.

The Federal specifications for 3½ per cent nickel carbon steel call for 3.25 to 3.75 per cent of nickel, and 0.25 to 0.30 carbon. This steel has a tensile strength of 85,000 lb. per sq. in. and an elongation of 18 per cent. A hot-rolled 3½ per cent nickel medium-carbon steel, SAE 2330, when oil-quenched develops a strength up to 220,000 lb. per sq. in., and Brinell hardness from 223 to 424 depending upon the drawing temperature. Steels with more than 3.5 per cent of nickel are too expensive for ordinary structural use. Steels with more than 5 per cent nickel are difficult to forge, but the very-high-content nickel steels are used where corrosion-resistant properties are required. Standard 3½ per cent and 5 per cent nickel steels are regular products of the steel mills, although they are sold under many trade names. The first nickel-steel armor plate, with 3.5 per cent nickel, was known as Harveyized steel.

**Nickel sulphate.** A crystalline compound, $NiSO_4 \cdot 7H_2O$, used in nickel plating and for blackening brass and zinc. It is the most widely used salt for nickel-plating baths. It is known in the plating industry as Single nickel salts. It is prepared by dissolving nickel or nickel hydroxide in sulphuric acid. Nickel sulphate is sold in the form of crystals about the size of peas, and pea-green in color. The specific gravity is 1.98, and the melting point is 100°C. It is soluble in water. Double nickel salts is Nickel ammonium sulphate, $NiSO_4 \cdot (NH_4)_2SO_4 \cdot 6H_2O$, and is used for baths for plating on zinc.

**Nickel-tantalum alloy.** Nickel containing a percentage of tantalum in alloy. The usual composition is 70 per cent of nickel and 30 of tantalum. The alloy is hard but is easily rolled or drawn into wire. It is nonmagnetic and does not oxidize when heated to a high temperature. It is prepared by heating at a white heat a highly compressed mixture of the two metals in powdered

form, and is formed by diffusion rather than fusion. The metal is used for electrical resistance wires or for electrical apparatus.

**Nicrosilal.** An alloy cast iron developed by the British Cast Iron Research Association. It contains up to 5 per cent of silicon, 17 per cent nickel, and 3 per cent chromium. It is heat resisting and has a high resistance to distortion and cracking at high temperatures.

**Nitric acid.** Also called Aqua fortis, and Azotic acid. A colorless to reddish fuming liquid of the composition $HNO_3$, having a wide variety of uses for pickling metals, etching, and in the manufacture of nitrocellulose, pyroxylin plastics, dyestuffs, and explosives. It has a specific gravity of 1.530, boiling point of 86°C., and is soluble in water and in alcohol. Its fumes have a suffocating action, and it is highly corrosive and caustic. Fuming nitric acid is any water solution containing more than 86 per cent of acid and having a specific gravity above 1.480. Nitric acid is made by the action of sulphuric acid on sodium nitrate, or purified Chilean saltpeter, and condensation of the fumes. The acid is sold in various grades depending on the amount of water. The strengths of the commercial grades are 38, 40, 42, and 43°Bé. The grade usually known as aqua fortis is the 42°Bé., containing about 65 per cent of acid. It is usually shipped in glass carboys.

**Nitriding steel.** Low-alloy steels especially intended for surface hardening by the absorption of nitrogen. Any steel will absorb some nitrogen under special conditions; by some methods of hardening, especially casehardening by cyanide, part of the hardness of the case is due to nitrogen. But nitriding steels refer to those which are intended to be subjected to nitriding atmospheres. The surface hardness of nitrided steel may be up to 900 Brinell, and the steels are used for gages and tools, and for gears, shafts, and machine parts where great wear-resistance is desired. The patented process, with the special steel compositions required, was discovered by Dr. Adolph Fry, of the Krupp Works, and the patents are held by the Nitralloy Corporation of America. A typical composition of Nitralloy of the Ludlum Steel Company, is: carbon, 0.30 to 0.40; aluminum, 0.75 to 1.5;

chromium, 1 to 1.5; manganese, 0.6; molybdenum, 0.15 to 0.25. This is Nitralloy G. Nitralloy 115, of the Vanadium Alloys Steel Company, has 1.2 per cent of aluminum, 1.4 chromium, 0.20 molybdenum, 0.50 manganese. A nitrided case is formed by heating the metal in an ammonia atmosphere to a temperature of 875°F. for a long period and quenching. The ammonia gas decomposes, and the liberated nitrogen combines with the steel, forming nitrides of aluminum, chromium, and molybdenum. Nitrard, of the Firth-Sterling Steel Company, is a nitriding tool steel which gives an extremely hard case up to 1,200 Brinell; the core hardness is 400 to 650 Brinell. Nitrided steels can be softened, or denitrided, by heating in a fused mixture of potassium and sodium chlorides, which frees the nitrogen as a gas. Nitrided steels are also highly resistant to corrosion, except in contact with gasolines containing tetra-ethyl lead.

**Nitrocellulose.** A compound made by treating cellulose with nitric acid, using sulphuric acid as a catalyst. Since cotton is almost pure cellulose, it is the usual raw material. Waste cotton and cotton linters are employed after thoroughly scouring and digesting in a weak solution of soda. The cellulose molecule will unite with from 1 to 6 molecules of nitric acid. The weaker compounds are used for the manufacture of rayon, pyroxylin plastics, and lacquers. The higher nitrates, called Guncotton, are employed in making smokeless powders and other explosives. The original U.S. Government name for this explosive was Indurite, from the Indian Head Proving Ground. Mono-nitrocellulose, $9_{12}H_{19}O_9(NO_3)$, contains 3.8 per cent of nitrogen. Trinitro-cellulose, $C_{12}H_{17}O_7(NO_3)_3$, contains 9.13 per cent of nitrogen, and is the product used for celluloid manufacture, and the name Cellulose nitrate is preferred for the low nitrates. It is not detonated by a blow, but the higher compounds are easily exploded. Nitrocellulose is soluble in most alcohols, ether, and in esters, and is called Soluble cotton when employed for such uses as the making of solidified alcohol.

**Nitrogen.** An elementary substance, symbol N, which at ordinary temperatures is an odorless and colorless gas. The atmosphere contains 79 per cent of nitrogen in the free state. It is

nonpoisonous and does not support combustion. Small quantities of nitrogen are used in incandescent lamps to prevent arcing. Nitrogen atmospheres are also used for bright-annealing of steel. It can be combined with many metals to form nitrides and is thus applied to the hardening of steel, the usual source for this purpose being from ammonia. The natural nitrates, soda niter and niter, are employed for the making of nitric acid and explosives, but even for these uses they are being replaced by atmospheric nitrogen, which is being produced in greatly increasing quantities. Fixation of nitrogen is a term applied to any process whereby nitrogen from the atmosphere is transferred into nitrogen compounds such as ammonia, and Calcium cyanamide, $CaCN_2$, used for fertilizer and as a source of urea for molding compounds. The annual consumption of nitrogen compounds, or Fixed Nitrogen is about 2,000,000 tons, of which 85 per cent is made synthetically.

**Nitroglycerin.** A heavy, oily liquid known chemically as Glyceryl-trinitrate and having the empirical formula $C_3H_5(NO_3)_3$. It is made by the action of nitric acid on glycerin in the presence of sulphuric acid or some other substance having an affinity for water. It is a highly explosive compound, detonating upon concussion. Liquid nitroglycerin when exploded forms carbonic acid, $CO_2$, water vapor, nitrogen, and oxygen; 1 lb. is converted into 156.7 cu. ft. of gas. The temperature of explosion is about 6280°F. For use as a commercial explosive it is mixed with absorbents and molded into sticks known as dynamite.

**Nitrostarch.** An explosive compound made by treating starch with a mixture of nitric and sulphuric acids. It is used for blasting; as a military explosive it has the advantages of cheapness, insensitiveness to bullet fire, friction, and impact. Dry nitrostarch is highly inflammable and is treated with inert materials before use. It is a white, finely divided powder, similar to the original starch. It is insoluble in water. It is readily detonated, and in combinations is employed in trench-mortar shells and in grenades. Nitrostarch is also used in signal lights in mixtures with the nonexplosive signaling material. Grenite is nitrostarch mixed with 5 per cent of oil and a binding material.

It forms small, white granules and is used in grenades. Trojan explosive, used for grenades and trench mortar explosives, is a mixture of 40 per cent of nitrostarch with ammonium nitrate, sodium nitrate, and small amounts of inert materials added to stabilize and reduce the sensitiveness of the nitrostarch.

**Nondeforming steel.** Also called Nonshrinking steel. A group of alloy steels which have the characteristic that they do not easily deform, or go out of shape, when heat-treated. This property makes them suitable for making dies, gages, or tools that must be accurate. Nondeforming steel contains from 1 to 1.75 per cent of manganese, with or without chromium or other alloying elements. The carbon content is the same as tool steels of the same grade. The phosphorus, sulphur, and silicon impurities are kept as low as possible. The steels are oil hardening, and do not have the tough core of ordinary tool steels. They have low resistance to shock and are thus not suited to bending or forming dies, except when they have additional alloying elements.

The nondeforming steel marketed by the Cyclops Steel Company, under the name of Wando contains 1.05 per cent of manganese, 0.50 chromium, 0.50 tungsten, and 0.95 carbon. Mangano, of the Latrobe Electric Steel Company, contains about 1.60 per cent of manganese, 0.20 chromium, and 0.95 carbon. Stentor, of the Carpenter Steel Company, is a nondeforming tool steel containing 1.6 per cent of manganese, 0.25 silicon, and 0.90 carbon. It hardens at a low temperature range, 1400 to 1440°F., which aids in avoiding warpage. Exl-Die Steel, of the Columbia Tool Steel Company, has 1.15 per cent manganese, 0.90 carbon, 0.50 chromium, and 0.50 tungsten. Saratoga, of the Ludlum Steel Company, and Amcoh, of A. Milne & Company, have about the same composition. Truform, of the Jessop Steel Company, is an oil-hardening high-manganese steel with a low coefficient of expansion, used for making cutters and dies. Deward, of the Ludlum Steel Company, contains 1.55 manganese, 0.90 carbon, and 0.30 molybdenum. Paragon steel, of the Crucible Steel Company, has about this amount of manganese with 0.50 to 0.75 chromium and 0.25 vanadium. Kiski steel, of the Braeburn Steel

Company, is a similar steel. Some high-chromium steels are also called nondeforming. Ontario Steel, produced by Ludlum, is an air-hardening steel containing 11 per cent chromium, 0.75 molybdenum, 0.25 vanadium, 0.35 silicon, 0.30 manganese, and 1.45 carbon. Chromovan Steel, of the Firth-Sterling Steel Company, is a nondeforming, wear-resistant tool steel containing 12.5 per cent chromium, 1.6 carbon, 0.80 molybdenum, and 1 vanadium. It is used for thread rolling and coining dies. Invaro, of the same company, is an oil-hardening tool steel for intricate dies, taps, and special tools. It contains 1.15 per cent of manganese, 0.50 chromium, 0.50 tungsten, and 0.90 carbon. Hargus Steel, of the Ziv Steel and Wire Company, for blanking dies, reamers, and gages, contains 1 per cent manganese, 0.35 nickel, and 1.0 carbon. See also Chromium steel, and Manganese steel.

**Nonmagnetic steel.** Steel and iron alloys used where it is important that no magnetic circuits be set up or magnetic effects be induced. Manganese steel containing 14 per cent of manganese is nonmagnetic and casts readily but is not machinable. Nickel steel containing 25 per cent of nickel is also nonmagnetic but is costly. Many mills produce regularly nonmagnetic steels containing from 20 to 30 per cent of nickel. Manganese-nickel steels and manganese-nickel-chromium steels are nonmagnetic and may be arranged to combine desirable features of the nickel and manganese steels. The 18–8 austenitic chromium-nickel steels are also nonmagnetic.

**Nonshattering glass.** Also referred to as Shatterproof glass, or Safety glass, and when used in armored cars it is known as Bullet-proof glass. A material composed of two sheets of plate glass with a sheet of transparent resinoid between, the whole molded together under heat and pressure. When subjected to a severe blow, it will crack without shattering. The first of these was a German product marketed under the name of Kinonglas, which consisted of two clear glass plates with a cellulose nitrate sheet between, and was first used for protective shields against chips from machines. Nonshattering glass is now largely used for automobile and car windows. The original cellulose nitrate

interlining sheets had the disadvantage that they were not stable to light and became cloudy. Cellulose acetate was later substituted. It is opaque to actinic rays and prevents sunstroke but has the disadvantage of opening in cold weather, permitting moisture to enter between the layers. The acrylic resins are notable for their stability in this use; in some cases they are used alone without the plate glass, especially for aircraft windows. See Plexiglas. Vinyl acetate resins, as interlinings for safety glass, are weather resistant and will not discolor. Duplate is the trade name of the Duplate Corporation for a nonshattering glass. Other trade names are Triplex and Cel-O-Glass. Cellon, of the F. A. Hughes & Company, Ltd., is a nonshattering glass made with Trolitul, a Polystyrol resin. Its refractive index is about the same as flint glass, and it is resistant to acids and alkalies. The specific gravity is 1.05. Standard bullet-proof glass is from 1½ in., 3 ply, to 6 in., 5 or more ply.

**Norskalloy.** A trade name for pig iron produced from Norwegian ores containing vanadium and titanium. The standard grade contains from 4 to 4.5 per cent of total carbon, 0.5 to 1.5 of silicon, 0.20 manganese, 0.20 to 0.25 phosphorus, 0.30 to 0.40 vanadium, and 0.40 to 0.80 titanium. From 15 to 20 per cent of Norskalloy pig is added to mixtures where vanadium is required.

**Nuremberg gold.** An alloy used in the manufacture of low-priced "gold" articles. Its color is very close to that of gold, and it does not tarnish easily. The average composition is 90 per cent of copper, 7.5 per cent of aluminum, and 2.5 per cent of gold, but it may contain a much higher percentage of aluminum and also more gold. See also Shadke.

**Oak.** The wood of a large variety of oak trees, all of the natural order *Cupuliferae*, genus *Quercus*. The She-oak of Australia, African oak, and the Roble, or "oak," of Chile, are not allied to the true oaks. European oak, under various names, such as Austrian oak, and British oak, are from two varieties of the tree *Quercus robur*. The wood is light brown in color, with a coarse, open grain, firm texture, and weight of about 45 lb. per cu. ft.

American Red oak is from the tree *Quercus rubra*. It is also called Black oak. The heartwood is reddish brown, and the sapwood whitish. American white oak is from the tree *Q. alba*. The heartwood is brown, and the sapwood white. The grain of these species is coarse, but the texture is firm. Western white oak, *Q. garryana*, has a more compact texture and straighter grain. American oaks are widely distributed in the United States and Canada. Spanish oak, *Q. oblongifolia*, is native to California and New Mexico. The grain is finer and denser.

Oak is used for flooring, furniture, cask staves, and where a hard, tough wood is needed. For cabinetwork the boards are variously sawed at angles and quarters to obtain beautiful grain effects known as Quartered oak. Fumed oak is not a kind of oak, but a finish produced by the action of ammonia vapor. Burr oak, or Pollard oak, also known as Burrwood, is the wood of the decapitated European oak trees *Q. pedunculata* and *Q. sessiliflora*, of Great Britain. A pollard tree is one whose head has been cut for ornamentation purposes. The growth in height is permanently arrested and innumerable branches shoot out from the trunk, which produce humps, or "burrs," with the grain of the wood running in all directions. Burr oak is valued for ornamental work. The commercial red and white oaks have an average specific gravity when kiln dried of 0.69. The compressive strength perpendicular to the grain is 1,870 lb. per sq. in., and shearing strength parallel to the grain of 1,300 lb. per sq. in.

Oak extract, which is an important tanning material for the best grades of heavy leather, is chiefly from the bark of the chestnut-oak, *Q. prinus*, and from the tan-bark oak, *Q. densiflora*. The bark yields 10 to 14 per cent of tannin, but the extract contains 25 to 27 per cent of tannin.

**Oakum.** A substance used for caulking the seams of vessels and wooden tanks. It consists of old hemp ropes untwisted and pulled into loose fiber, and treated with tar.

**Ochre.** A compact form of earth used for paint pigments and as a filler for linoleum. It is an argillaceous and siliceous material, often containing compounds of barium or calcium, and owing the yellow, brown, or red colors to hydrated iron oxides.

The tints depend chiefly upon the proportions of silica, white clay, and iron oxide. Ochres are very stable as pigments. They are prepared by careful selection, washing, and grinding in oil. They are inert, and are not affected by light, air, or ordinary gases. They are rarely adulterated, because of their cheapness, but are sometimes mixed with other substances to alter the colors. Chinese yellow and many other names are applied to the ochres. Golden ochre is ochre mixed with chrome yellow. White ochre is ordinary clay. A large part of the American ochre is produced in Georgia. Sienna is a brownish-yellow ochre found in Italy and Cyprus. The material in its natural state is called Raw sienna. Burnt sienna is the material calcined to a chestnut color. Indian red and Venetian red are hematite ochres. The best Venetian reds are made by heating the ochres. See also Umber, and Ferric oxide.

**Oil asphalt.** The heavy, black residue left after removing the tar tailings in the distillation of petroleum. It is a thick fluid, or a solid, depending upon the amount of distillate removed from the crude oil. It contains more than 99 per cent of bitumen and only about 0.3 per cent of mineral matter; natural Trinidad asphalt contains only 56 per cent of bitumen and 37 per cent of mineral matter. Oil asphalt is little affected by water and does not decay readily. It adheres well to paper, wood, and metals, forming a brilliant surface. It is used for making roofing and for mixing with natural asphalt for paving, paints, and other uses. It is marketed in steel drums of 400 net pounds each. A gallon of oil asphalt weighs 8.33 lb. For road making it may be called Asphalt oil. See also Asphalt, and Rafaelite.

**Oilcloth.** A fabric of woven cotton, jute, or hemp, heavily coated with turpentine or paints, usually ornamented with printed patterns, and varnished. It is employed chiefly as a floor covering, but a light, flexible variety having a foundation of muslin is used as a covering material. This class comes in plain colors or in printed designs.

**Oil gas.** Also called Carbo-hydrogen. A class of gases produced by allowing petroleum oils to drop on heated brick-

work in a closed retort, or by otherwise "cracking" the oil. These gases give a low-temperature flame and are used for flame cutting torches. They are chemically broken down so that gases containing as high as 85 per cent of hydrogen are obtained commercially in this way. The balance of the gas consists of light hydro-carbons. Oil gas is marketed compressed into steel cylinders. Pintsch gas, formerly used for car lighting, contained 50 to 60 per cent of methane.

**Oils.** A large group of fatty substances which are divided into three general classes: vegetable oils, animal oils, and mineral oils. The vegetable oils are either "fixed" or "volatile" oils. The fixed oils are largely glycerides of stearic, oleic, palmitic, and other acids, and they vary in consistency from light fluidity to solid fats. They nearly all boil at 500 to 600°F., decomposing into other compounds. The volatile, or Essential, oils bear distillation without chemical change. They are derived from plants and are usually the substances upon which the odoriferous properties of the plants depend. They are soluble in alcohol, ether, or benzol. Oils are found in all plants, particularly in the seeds, and in nearly all parts of animal bodies. Fish oils are thick, with a strong odor. Vegetable and animal oils are obtained by pressing, extraction, or distillation. Oils that absorb oxygen easily and become thick are known as drying oils and are valued for varnishes, because on drying they form a hard, elastic, waterproof film. Oils and fats are distinguished by consistency only, but waxes are not oils, and upon saponification produce alcohol and fatty oils instead of glycerin. Mineral oils are derived from petroleums. See Petroleum.

**Oilskin.** A cotton or linen fabric impregnated with oils to make it waterproof. It is used for large sheet coverings for cargo, and for the waterproof coats known as Oilskins. Oiled silk is a thin silk fabric impregnated with boiled linseed oil. It is also waterproof, very pliable, and semitransparent. It is used for linings. Oilskins are now largely replaced by rubberized fabrics, or by fabrics coated or impregnated with synthetics.

**Oilstone.** A fine-grained, slaty silica rock used for sharpening edged tools. The bluish-white and opaque white oilstones

of fine grain from Arkansas are called Novaculite, and received their name because they were originally used for razor sharpening. They are composed of 99.5 per cent of chalcedony silica and are very hard with a fine grain. Novaculite is a deposit from hot springs. It is fine-grained and bluish white in color. The finest stones are used for oilstones, and the ordinary grades are employed for the production of silica refractories. Arkansas oilstones are either hard or soft and have a waxy luster. They are shipped in large slabs or blocks. Washita oilstone, from Hot Springs, Ark., is a hard, compact white stone of uniform texture. Onachita stones come in larger and sounder pieces but are coarser than the Arkansas. Water-of-Ayr stone, also known as Scotch hone, is a fine sandstone used with water instead of with oil. Artificial oilstones are also produced of aluminum oxide. India oilstone was originally blocks of emery, but the name now may refer to aluminum oxide stones. See Whetstone.

**Oleic acid.** Also called Red oil, and Elaine oil. An organic acid having a complex composition, represented empirically by the formula, $CH_3[(CH_2)_7CH]_2COOH$. It is used in making soluble oils and cutting compounds, in which it forms Sodium oleate, $C_{17}H_{33}COONa$. It is also used in the manufacture of oil-soluble colors and of soft soaps. Oleic acid is found in most fats in combination with glycerol, particularly in liquid fats, or oils, such as olive oil, oleo oil, cottonseed oil, and coconut oil. It can be separated from fats by saponification and is obtained by distillation. It is an oily liquid with a specific gravity of 0.890, boiling point of 222°C., and freezing point of −10°C. It is soluble in alcohol. The two commercial grades of oleic acid are known as saponified and distilled red oil.

**Olivine.** A translucent mineral, usually occurring in granular form, employed as a refractory. It is a silicate of iron and magnesium, or a solid solution of Forsterite, $2MgO \cdot SiO_2$, and Fayalite, $2FeO \cdot SiO_2$. The fayalite lowers the refractory quality, but forsterite is not found alone. Dunite deposits in North Carolina yield material carrying up to 90 per cent olivine which has only 5 to 15 per cent of fayalite. It is olive-green in color, vitreous, with a hardness of 6.5 to 7 and a specific

gravity of 3.3 to 3.5. As a refractory it is neutral up to about 1600°C. but may then react with silica. The fayalite fuses out at 2700°F., making the material porous and subject to attack by iron oxide. The softening point of forsterite is 3245°F. When used mixed with chrome ore, the low-fusing elements form a black glass which presents a nonporous face. Some refractory material marketed as forsterite may be olivine blended with magnesite, or may be serpentine treated with magnesite. The thermal expansion of olivine is lower than that of magnesite. Olivine sand is substituted for silica sand as a foundry sand where silica is expensive. There are large deposits of olivine in the Pacific Northwest. When used as a foundry sand, it is noted that the heat-resisting qualities decrease with particle size.

**Onyx.** A variety of mineral differing from agate only in the straightness of its different layers. It is a chalcedony silica. The alternate bands of color are usually white and black, or white and red. Onyx is artificially colored in the same way as agate. It is used as an ornamental building stone, usually cut into slabs, and for decorative articles. Onyx marble is limestone with impurities arranged in banded layers. Mexican onyx is banded limestone obtained from stalactites in caves. These materials are cut into such articles as lamp stands. Argentine onyx is a dark green or a green-yellow translucent stone of great decorative beauty. In the United States it is called Brazilian onyx and is used for book ends, lamp bases, ink stands, and ornaments. Agatized wood, found in the petrified forest of Arizona, is cut into gems and ornaments, as is also Opalized wood, an agate or onxy-like material from Idaho.

**Open-hearth steel.** Steel made by the process of melting pig iron and steel or iron scrap in a lined regenerative furnace, and boiling the mixture, with the addition of pure lump iron ore, until the carbon is reduced. The boiling is continued for a period of 3 or 4 hr. The process was developed in 1861 by Siemens in England. The furnaces are made in sizes from 10 to 300 tons capacity, and contain regenerative chambers for the circulation and reversal of the gas and air. The fuels used are natural gas, fuel oil, coke-oven gas, or powdered coal. Both the acid- and

basic-lined open-hearth furnaces are used, but most steel made in the United States is basic open hearth. Ganister is used as a lining in the acid furnaces, and magnesite in the basic.

An advantage of the open-hearth furnace is the ability to handle raw materials that vary greatly and also to employ scrap. The duplex process consists in melting the steel in an acid Bessemer furnace until the silicon, manganese, and part of the carbon have been oxidized, and then transferring to a basic open-hearth furnace where the phosphorus and the remainder of the carbon are removed. Open-hearth steel is of uniform quality. The open-hearth steel bars used by one large company contains 0.08 to 0.18 per cent of carbon, a maximum of 0.55 per cent of manganese, 0.05 of phosphorus, and 0.06 per cent of sulphur. With 0.12 per cent of carbon open-hearth steel has a tensile strength of 55,000 lb. per sq. in. and an elongation of 27 per cent; the same steel with 0.18 per cent of carbon has a tensile strength of 68,000 lb. and an elongation of 23 per cent.

**Optical glass.** A highly refined glass, usually a flint glass, of special composition, or made from rock crystal, used for lenses and prisms. It is cast, rolled, or pressed. In addition to the regular glass-making elements, silica and soda, optical glass contains barium, boron, and lead. The highly refractory glasses contain abundant lead oxide or barium oxide, and the low-refracting glasses contain abundant silica or boron oxide. A requirement of optical glass is transparency and freedom from color. Traces of iron make the glass greenish, while manganese causes a purple tinge. First-quality optical glass should contain a minimum of 99.8 per cent of $SiO_2$. Borax is used in purifying and in increasing the strength and brilliance of the glass. Besides the control of chemical composition, careful melting and cooling are necessary to obtain fine transparency, and then intense polishing. The pouring temperature is about 1200°C. The best optical glass has a transparency of 99 per cent, compared with 85 to 90 per cent for ordinary window glass.

**Ore.** A metal-bearing mineral from which a metal or metallic compound can be extracted commercially. Earths and

rocks containing metals that cannot be extracted at a profit are not rated as ores. Ores are named according to their leading useful metals. The ores may be oxides, sulphides, haloids, or oxygen salts. A few metals also occur native in veins in the minerals. Ores are usually crushed and separated and concentrated from the gangue with which they are associated.

The metal content to make an ore commercial varies widely with the current price of the metal, and also with the content of other metals present in the ore. Normally, a sulphide copper ore should have 1.5 per cent of copper in the unconcentrated ore, but if gold or silver is present an ore with much less copper is workable. Likewise, low-grade lead ores can be worked if silver is recoverable. Low-grade manganese and other ores become commercial when the prices are high.

**Oreide bronze.** A very old term for a high-copper brass having a color somewhat like gold when polished. It was originally used for carriage and harness hardware, but now finds use for ornamental parts where the gold color is desired. The alloy contains 87 per cent of copper and 13 zinc. It casts well. See Rich low brass.

**Orpiment.** A mineral used as a pigment. It is an Arsenic trisulphide, $As_2S_3$, containing 39 per cent of sulphur and 61 per cent of arsenic, and is found in Central Europe, Peru, and in Utah. It has a foliated structure, a specific gravity of 3.4, hardness of 1.5 to 2, a resinous luster, and a lemon-yellow color. Artificial Arsenic sulphide is now largely substituted for natural orpiment. It is referred to as King's yellow.

**Osmium.** A rare metal, symbol Os, having the highest specific gravity, 22.50, and a very high melting point, 4890°F. Osmium forms a solid-solution alloy with platinum. Compared with iridium it has more than double the hardening power on platinum, but it volatilizes so readily into the poisonous tetroxide that it is seldom used to replace iridium in platinum alloys. With iridium, however, it is used as an alloy for fountain-pen tips under the name of Osmiridium. Osmium is not affected by the common acids and is not dissolved by aqua regia. The

metal is sold by the troy ounce, 1 cu. in. of osmium weighing 11.86 troy oz.

**Osnaburg cloth.** Heavy, coarse cloth of plain weave made from waste and scraps of cotton mills, or from low-grade short-staple cotton. It is employed to replace burlap for wrapping and baling and is a standard material in 7.8-oz. weight for inside sacks for burlap flour sacks. In checks and stripes the cloth is used for protective coverings, often waterproofed.

**Ounce metal.** A copper casting alloy which is a "standard composition metal," neither a brass nor a bronze. It contains 85 per cent of copper, 5 of tin, 5 of zinc, and 5 of lead. It is used as a bearing metal and for casting valves, carburetor and pump parts, and similar mechanical pieces. The name was derived from the fact that originally one ounce each of the white metals was added to one pound of copper. It has a tensile strength of 27,000 to 33,000 lb. per sq. in., elongation of 15 to 20 per cent in 2 in., reduction of area of 15 to 20 per cent, Brinell hardness of 50 to 59, specific gravity of 8.6, and weight of 0.31 lb. per cu. in. It casts well and machines easily. See Composition brass.

**Oxalic acid.** An organic acid of the composition $(COOH)_2$ plus water of crystallization, employed as a bleaching agent for leather, cork, wood, shellac, and as a stain remover from fabrics and porcelain. It occurs in colorless crystals with a specific gravity of 1.653 and melting point of 187°C. It is soluble in water and in alcohol. Oxalic acid is obtained by the action of nitric acid on strong alkalies.

**Oxygen.** The most important and abundant of the elements. Its chemical symbol is O. It constitutes about 89 per cent of all water, 33 per cent of the earth's crust, and 21 per cent of the atmosphere. It combines readily with all elements except fluorine, helium, and argon. It is a colorless and odorless gas and can be produced easily by the electrolysis of water. The specific gravity is 1.1056. It liquefies at −113°C. at 59 atm. Liquid oxygen is a pale, steel-blue, transparent, mobile liquid. Oxygen is the least refractive of all gases. It is the only gas

capable of supporting respiration, but is harmful if inhaled pure for a long period. In small quantities it is an exhilarant. Oxygen has many commercial uses and is marketed in steel cylinders under a pressure of 2,000 lb. per sq. in. The chief use is for oxy-acetylene welding and metal cutting. For welding it should be at least 99.5 per cent pure. See Acetylene. Oxygen for bleaching purposes is obtained from substances that readily yield the gas such as the liquid Hydrogen peroxide, $H_2O_2$, or the granular solid Sodium peroxide, $Na_2O_2$. Albone is the trade name of a hydrogen peroxide for this purpose produced by E. I. du Pont de Nemours & Company, Inc. It has 13 per cent of available active oxygen. Solozone is the name of a sodium peroxide of the same company having 20 per cent of available oxygen. Ozone is an allotropic form of oxygen and is composed of three atoms of oxygen, $O_3$. It is formed by electric discharges in the air, or during the evaporation of water, particularly of spray in the sea. It has a peculiar odor, which can be detected in 500,000 parts of air. Ozone is a powerful oxidizer, destroying most organic compounds and bleaching vegetable colors. Pure ozone is an irritant poison, but in minute quantities in the air is purifying and healthful. As an oxidizer in the rubber industry it is known as Activated oxygen.

**Ozokerite.** Also known as Mineral wax, and as Earth wax. A natural paraffin found in Utah and in central Europe, and used as a substitute or adulterant of beeswax, and in polishes, phonograph records, and insulation. Ozokerite is a yellowish to black, greasy solid, melting at about 75°C. and having a specific gravity of 0.85 to 0.95. It is soluble in alcohol, benzol, and naphtha but not in water. The wax occurs in rocks, which are crushed, and the wax melted out. The latter is then refined by boiling, treating with an alkali, and filtering. The refined and treated ozokerite is called Ceresin. A similar wax, called Montan wax, is produced in Saxony from lignite. Ceresin and other mineral waxes are sold in white, waxy cakes.

**Paint.** A general name to designate a solution of a pigment in water, oil, or organic solvent, and used to cover wood or metal articles either for protection or for appearance. Paints

always contain pigments; the solution of gums or resins, known as varnishes, are not paints, although their application is usually termed painting. Enamels and lacquers, in the general sense, are under the classification of paints, but specifically the true paints do not contain gums or resins. Stain is a trade name for a varnish containing enough pigment to alter the appearance or tone of wood in imitation of another wood. Enamel paint is also a pigment in varnish. The vast bulk of paint is made with about 65 per cent by weight of pigment and 35 of vehicle. The best House paint for outside work consists of high-grade pigment and linseed oil, with a small percentage of turpentine as a thinner and a drier. The volatile thinner in paints is for ease of application, the drying oil determines the character of the film, the drier is to speed the drying rate, and the pigment gives color and hiding power. Paints are marketed in many grades, containing pigments adulterated with silica, talc, barytes, gypsum, or other material; fish oils, or inferior semi-drying oils in place of linseed oil; and mineral oils in place of turpentine. Metal paints contain basic pigments such as red lead, ground in linseed oil, and should not contain sulphur compounds. The composition of paints is based on relative volumes since the weights of pigments vary greatly, although the custom is to specify pounds of dry pigment per gallon of oil. A "28-lb." red-lead paint is one that contains 20.3 lb. of red lead per gallon and weighs 25.9 lb. per gallon. Bituminous paints are of coal-tar or asphalt products, dissolved in mineral spirits, and used for the protection of pipes, and for water-proofing cement. Water paints consist of gypsum or whiting with zinc oxide, lithopone, or other material, and with water as the vehicle. They usually also contain glue for adhesion. They are moderate in price, but not durable. Luminous paints are made with radium, mesothorium, or with sulphurated compounds. There are two classes, Radioactive paints and Phosphorescent paints. The latter, with zinc sulphide, are cheaper but are not durable. The hiding power of a paint is defined as that quantity which must be applied to a given area of a black and white background to obtain nearly uniform complete hiding. See also Pigments, Drying oils, Driers, Enamels.

**Palladium.** A rare metal found in the ores of platinum, symbol Pd. It resembles platinum, but is lighter in weight and has a more beautiful silvery luster. It is only half as plentiful but is less costly. The specific gravity is 12.16 and the melting point is 1549°C. The Brinell hardness of the annealed metal is 49. It is a white metal, and is highly resistant to corrosion and to the action of acids. Like gold, it dissolves in aqua regia. It alloys readily with gold and is employed in some grades of white gold. It also forms solid solutions with platinum, and the alloys are harder than either of the constituent metals. These alloys are easily workable and are employed for instruments and jewelry. Palladium is also used as a plating metal for such articles as electrical appliances. Palladium leaf is palladium beaten into an extremely thin foil used for ornamental work like gold leaf on pocketbooks, picture frames, and decorative surfaces. It has a white color and is resistant to tarnishing even when exposed to sulphur atmospheres. A book of 500 sheets, or 35 sq. ft. of leaf, weighs less than ¼ oz. Palladium-silver alloys are used for fountain-pen nibs. A dental alloy to replace gold contains 20 to 30 per cent of palladium, up to 15 copper, and the remainder silver. Palladium sponge absorbs much hydrogen and is used for gas lighters.

**Palm oil.** An oil obtained from the fleshy covering of the seed nuts of several species of palm trees, chiefly *Elaeis guineensis*, native to tropical Africa. The largest use of the oil is as a fluxing dip in the manufacture of tin plate, but it is also used for soaps, candles, and butter substitutes. Fresh palm oil has an agreeable odor and a bright orange color, but the oil often has a rancid stench and is of varying colors. Palm oil contains from 50 to 70 per cent of Palmitic acid, $C_{16}H_{32}O_2$, which is an ingredient of most fats. The tree attains a height of about 60 ft., and the nuts occur in large bunches similar to dates. The fruit is of an elongated ellipse shape, about 1½ in. long, enclosing usually a single kernel. The fleshy part carries about 65 per cent of oil, which is a semisolid fat. The iodine value is about 55, and the saponification value 205. Palm oil for tin-plate dip may be mixed with cottonseed or mineral oil.

**Paper.** The name given to cellulose made into paste form from plant sources and rolled into thin sheets, used as a material for writing, printing, and wrapping. There are many varieties and grades of paper, depending upon the source of the cellulose and the method of manufacture. Spruce, hemlock, pine, or other woods form the chief source of cellulose for paper, but wood is a lignified form of cellulose, and the wood is chipped and cooked with chemicals to dissolve out the lignin. The material so treated is known as Chemical wood pulp to distinguish it from Mechanical wood pulp used for making wallboard and newsprint paper, the latter requiring some chemical pulp to give fiber and strength. There are three processes for producing chemical pulp; the sulphite, with calcium sulphite; the soda, with caustic; and the sulphate, with sodium sulphate. Book paper is usually a mixture of sulphate and Soda pulp, the latter process producing a bulky pulp. Wrapping paper is a strong, coarse paper made usually from mixed pulps. Kraft paper is a heavy brown sulphate pulp paper of high strength, sized with rosin, used for wrapping or as a building paper. Manila paper is a strong wrapping paper originally made from Manila hemp, but the name is now applied to any strong chemical wood-pulp or mixed pulp paper, of Manila color. Absorbent paper, such as for Blotting paper and Filter paper, is made from spongy bulky fibers, such as poplar, or is loosely felted fiber. Granite paper is made by adding a small percentage of colored fibers to the pulp or by adding several shades of dyed pulp to the regular stock. Oatmeal paper, used chiefly for wallpaper, has a flaky finish produced by washing a solution of wood flour over the sheet on the forming wire in the paper machine. The wood flour may be natural or dyed in colors.

Cartridge paper is 50–80-lb. Manila paper waxed on one side, used for containers for dynamite. Glassine is a transparent thin paper used for envelope windows and for sanitary wrapping. It is made of sulphite pulp subjected to long-continued beating and super-calendered. Glassoid is a more highly finished transparent paper. Onionskin paper is a light-weight, highly-finished, transparent writing paper made transparent by hydration of the pulp in the beaters.

Cotton is nearly pure cellulose and makes an excellent paper material. Old cotton rags are thus scoured and used for papermaking. Linen fabrics are also used and produce a fine grade of writing paper. The best quality writing and printing papers are 50, 75, or 100 per cent rag papers. Bond paper is a hard-finished writing paper. Highly rolled and coated printing papers are called Super-calendered papers. They are used for printing fine-screen half tones. In England this paper is called Art paper. Fine linen Ledger paper is made with 100 per cent white rags. Good quality bond Typewriter paper may have 80 per cent white rags. To make paper smooth-surfaced and resistant to the spreading of inks, sizing materials such as resins, starch, alum, and glue are used. Fillers, such as China clay, are used to give body, weight, opacity, and strength to the paper. Paper may be partly waterproofed with a copper-ammonium solution and hot rolled. See also Parchment. Fish paper is a thin hard paper impregnated with zinc chloride and is used for electric insulation. See Armite. Flame-proofed paper is paper treated with ammonium sulphate and ammonium and sodium phosphates. Ordinary papers are sold by weight per ream, a ream usually consisting of 500 sheets of a specified size in inches. Building paper, used for sheathing houses, is a heavy kraft paper, plain or rosin-sized. Specially treated building papers are also marketed under trade names. Weatherite, of Johns-Manville, is a kraft building paper treated with a black waterproofing. Copperskin is an insulating construction material made by facing 1-oz. electro-sheet copper on one or two plies of heavy building paper impregnated with bitumen. Cop-O-Top, of the Chase Brass & Copper Company, and Copperkote of the Cheney Company, are similar materials. Sisalkraft, of the Sisalkraft Company, is a waterproof building paper made with sisal fibers. Brownskin is a waterproof sheathing paper of the Angier Corporation of high-strength building paper impregnated with a bituminous compound and crimped to give it stretch and resiliency. Sta-Tite, of this company, is a building paper composed of three sheets of Kraft paper with layers of asphalt between in which are set a layer of crossed cords and one of parallel cords. Burlap-lined paper, used for wrapping

leather and machinery, is heavy kraft paper coated with asphalt to which 4- to 10-oz. burlap is struck.

**Papier maché.** Comminuted paper or paper pulp made into a paste with a binder, and molded into the desired form. It is then painted or enameled, or the paste itself may be dyed. Papier mâché, originated in France in 1740, was widely employed for toys, dishes, and novelties before the invention of the synthetic molding materials. It is easy to mold, but has little strength and is not suited for mechanical parts. Dishes and novelties now made of paper stock are usually made directly from the wood pulp or paper-mill product.

**Paraffin.** A general name often applied to paraffin wax, but more correctly referring to a great group of hydrocarbons obtained from petroleum. Paraffin compounds begin with methane, $CH_4$, and are sometimes called the methane group. The substances in the series have the general formula $C_nH_{n+2}$, and include the gases methane and ethane, and the products naphtha, benzine, gasoline, lubricating oils, vaseline, and the common paraffin. The name paraffin indicates little affinity for reaction with other substances. In common practice the name is limited to the paraffin waxes that follow vaseline in the distillation of petroleum. These waxes melt at from 48 to 55°C., and consist of the hydrocarbons between $C_{22}$ and $C_{27}$. They burn readily in the air. Paraffin occurs to some extent in some plant products, but its only commercial source is from natural petroleum.

**Paraffin oil.** The drip oil from the wax presses in the process of extracting paraffin wax from the wax-bearing distillate in the refining of petroleum. The oil is treated, redistilled, and separated into various grades of lubricating oils from light to heavy. They may be treated and bleached with sulphuric acid, and neutralized with alkali. When decolorized with acid and sold as filtered, they are brilliant liquids, but are not suitable as crankcase lubricants, or in places where they may be in contact with water, since the "sulpho" compounds present cause emulsification. The specific gravities of paraffin oils are between 21 and 26° Bé.

**Paraffin wax.** The first distillate taken from petroleum after the cracking process is known as wax-bearing, and is put through a filter press and separated from the oils. The wax collected on the canvas plates is called Slack wax, and contains 50 per cent of wax, and 50 of oil. This is put through a sweating process which frees it from the oil. The sweated wax is separated into grades with melting points varying from 105 to 136°F. The yellow wax may be melted and filtered to make refined wax, which is colorless, odorless, and tasteless. Paraffin wax is soluble in ether, benzine, and essential oils. Match wax has a melting point of 105 to 112°F.; white crude wax, 111 to 113°F.; yellow crude, 117 to 119°F.; semirefined, 122°F.; and special white, 124 to 126°F. The refined waxes are in various melting point ranges from 115 to 132°F. The refined paraffin wax used for molded goods and for rubber compounding is a white solid having a melting point of 122°F. and a specific gravity of 0.903. Wax is marketed in barrels, 20-lb. slabs, and cases. It is used for sealing, waterproofing paper, as a filler for leather, and for many other things. Wax tailings is the name for the distillate that comes from petroleum after the wax-bearing distillate is removed. It contains no wax, but at ordinary temperatures looks like beeswax. It is very adhesive and is employed in roofings and for waterproof coatings.

**Parchment.** A very hard and tough paper used for documents. It resists soaking in water and lasts for long periods. It is made by dipping heavy cellulose paper into cold, strong sulphuric acid and then washing in water. Parchment and papers are also waterproofed by dipping in the solution of copper hydroxide and ammonium hydroxide known as Schweitzer's reagent, and then hot rolling. Vellum is a thick grade of writing paper made in imitation of calfskin. It is produced from high-grade rag pulp.

**Parsons' alloy.** One of the earliest forms of "manganese bronze," patented in 1876 by P. M. Parsons. A typical analysis is 56 per cent of copper, 41.5 of zinc, 1.20 of iron, 0.70 of tin, 0.10 of manganese, and 0.46 of aluminum. The tensile strength of this alloy is 70,000 lb. per sq. in., elongation 25 per cent,

and the Brinell hardness 104 to 119. The specific gravity is 8.4. See Manganese bronze.

**Pasteboard.** A class of thick paper used chiefly for making boxes and cartons, and for spacing and lining. It may be made by pasting together several single sheets, but more usually by macerating old paper and rolling into heavy sheets. It may also be made of straw, certain grasses, and other inferior paper materials, and is then known as Strawboard. Colloquially, the term pasteboard applies to any paper-stock board used for making boxes. Cardboard is usually a good quality of chemical pulp or rag pasteboard used for cards, signs, or printed material, or for the best quality boxes. Ivory board, for art printing and menu cards, is a highly finished cardboard clay-coated on both sides. Bristol board is a high-class white cardboard, supercalendered with china clay, or it may be made by pasting together sheets of heavy ledger paper, but the name is also applied to any high-grade printing or drawing board over 0.006 in. thick. Index bristol is always made solid on a Fourdrinier machine to prevent splitting in use or warping. The original board made in Bristol, England, was made in this way. Jute board, used for folding boxes, is a regular product of the paper mills, and is a strong solid board made of kraft pulp. Chipboard is a cheap board made from mixed scrap paper, used for boxes and book covers. When made with a percentage of mechanical wood pulp, it is called Pulpboard. A heavy rope-pulp paper or board, usually reddish in color and used for large expansion filing envelopes, is called Paperoid.

**Patronite.** One of the chief ores of the metal vanadium. It is worked chiefly in Peru, but it also occurs in other places. It is a greenish sulphide of vanadium with approximately the formula $V_2S_9$, but often associated with pyrites and carbonaceous matter. It has a specific gravity of 2.71, and when calcined loses about 45 per cent of its weight.

**Pattern woods.** Sugar pine is the most widely used wood for patterns employed in all kinds of foundry work in the United States. It replaces Eastern white pine, which is scarcer and now usually more costly. See Sugar pine. Poplar is used

for patterns where a firmer wood is desired; cherry or maple is employed where the pattern is to be used frequently or will be subject to severe treatment. Mahogany is used for small and intricate patterns where a firm texture and freedom from warpage are needed. However, for small castings made in quantities on gates, aluminum or brass is more frequently used.

**Paving sand.** A type of commercial sand which is divided into three general classes, that for concrete pavements, that for asphaltic pavements, and that for grouting. Sand for concrete pavements, according to the U.S. Bureau of Public Roads, should all pass through a ¼-in. screen, 5 to 25 per cent should be retained on a No. 10 sieve, from 50 to 90 per cent on a No. 50 sieve, and not more than 10 per cent should pass through a No. 100 sieve. Not more than 3 per cent of the weight should be matter removable by elutriation. For asphaltic pavements small amounts of organic matter are not objectionable in the sand. All should pass through a ¼-in. screen, 95 to 100 per cent through a No. 10 sieve, and not more than 5 per cent through a No. 200 sieve. Grouting sand should all pass through a No. 10 sieve, 80 per cent through a No. 20 sieve, and 5 per cent through a No. 200 sieve. See Building sand.

**Peanut oil.** Also known as Ground-nut oil. A pale yellow oil with a distinctive nutty taste and odor, obtained from the pressing of the common peanut. The best grades of cold-pressed oils are marketed as edible oils, but the oil is also used industrially for soaps and for blending in lubricating and varnish oils. The specific gravity is from 0.916 to 0.922, saponification value 189 to 196, and iodine value 83 to 101. The oil known as Arachis oil, or as Katchung oil when imported from the Orient, is from the peanut *Arachis hypogaca*. It is used in lubricating, for varnishes, and for softening leather. Another edible oil used for lubrication and in soaps is Olive oil. The industrial oil consists of the "foots" or third pressing. It is a pale greenish oily liquid, and is the oil used in Castile soap.

**Peat.** An earthy mass formed by the rapid accumulation of quick-growing mosses and plants, and valued as a fuel in

countries where other fuels are expensive. In the United States it is used for fertilizer, for insulation, and for packing. The dried Peat moss is used for making insulating board. Peat bogs, or beds, are found mainly in moist districts in temperate climates. The top layers are only slightly decayed, are brown in color, and of low specific gravity. But at greater depths peat is nearly black and is very compact. The reserves of peat are very large, especially in the states bordering on the Great Lakes. Fresh peat often contains as high as 80 per cent of moisture and must be dried before use. Wicklow dried peat contains about 71 per cent of volatile matter, 27 per cent being fixed carbon, and 28 per cent coke. The calorific value of peat is about 5,000 B.t.u. It is sometimes semicarbonized and made into fuel briquettes. Charred peat is peat that has been subjected to a temperature to cause partial decomposition. It is marketed as fertilizer. Peat is also distilled, yielding mainly gas and tar.

**Perilla oil.** A light yellow oil obtained from the seeds of the plant *Perilla ocimoides* of China and Japan, and employed as a substitute for linseed oil in varnishes and core oils. The specific gravity is about 0.940, iodine value 200, and saponification value 191. Its disadvantage is its property of forming drops or globules when the varnish is spread on a hard surface.

**Permeability alloys.** A general name for iron-nickel alloys possessing a magnetic susceptibility much greater than iron. An alloy developed by H. D. Arnold and G. W. Elmen had a composition determined by experiment and was made up theoretically of 78.5 per cent of nickel, 21.5 iron, but with other elements approximately as follows: carbon, 0.04 per cent; silicon, 0.03; cobalt, 0.37; copper, 0.10; and manganese, 0.022 per cent. It is produced by the Western Electric Company, sometimes with chromium or molybdenum, under the name of Permalloy, and is used in the construction of magnetic cores for apparatus which operates on feeble electric currents, and in the loading of submarine cables. It has very little magnetic hysteresis. Another permeability alloy known as Mumetal, of the Telegraph Construction & Maintenance Company, Ltd., has 76 per cent of nickel, 6 copper, and 1.5 chromium. Permafy

is a French alloy of this type. It has a lower initial permeability than the plain nickel-iron type, but has a higher resistivity to keep down eddy current losses. Perminvar, of the Western Electric Company, is an alloy containing 45 per cent of nickel and 25 cobalt, intended to give a constant magnetic permeability for variable magnetic fields. A-metal is a nickel-iron alloy containing 44 per cent of nickel and a small amount of copper. It is used in transformers and loud-speakers to give nondistortion characteristics. Permax is a French high-permeability alloy of nickel and iron with small additions of manganese and other elements. Conpernick, of the Western Electric Company, contains equal amount of nickel and iron with no copper. It is called constant permeability nickel, as it has a wide range of flux density with little permeability variation. It differs from Hipernick, of the Westinghouse Electric & Manufacturing Company, only in the heat treatment. When heat-treated, the permeability is higher than that of silicon transformer steel. Both alloys are used for transformer cores. Vicalloy, developed by the Bell Laboratories, is a high-permeability alloy containing 36 to 62 per cent of cobalt, 6 to 16 vanadium, and the balance iron. It is cast and hot-swaged, then drawn into wire or tape as fine as 0.002 in.

The iron-nickel permeability alloys are used as loading by wrapping a continuous layer around the full length of the cable. When nickel-copper alloys are used, they are employed as a core for the cable. Magnetostrictive alloys are iron-nickel alloys which have the characteristic that they will resonate when the frequency of the applied current corresponds to the natural frequency of the alloy. They are used in radios to control the frequency of the oscillating circuit.

**Persimmon wood.** The wood of the persimmon tree, *Diospyros virginiana*, of the Southeastern United States. It is used for shuttles, golf-stick heads, tools, and takes a fine polish. The tree belongs to the ebony family. The wood is very hard, strong, and compact. The sapwood is light-brown in color, and the heartwood is black. The weight is 49 lb. per cu. ft. A fine wood used for fancy articles is Olive wood, from the olive

fruit tree of California. The wood is yellowish with beautifully streaked dark lines.

**Petrolatum.** A jellylike substance obtained in the fractional distillation of petroleum. Its composition is between $C_{17}H_{36}$ and $C_{21}H_{44}$, and it distills off above 303°C. It is also called Petroleum jelly. It is used for lubricating purposes and for compounding with rubber and resins. When highly refined for the pharmacy trade, it is called Vaseline. The specific gravity ranges from 0.820 to 0.865. It is insoluble in water but readily soluble in benzine and in turpentine. For lubricating purposes it should be refined by filtration only and not with acids, and not adulterated with paraffin. The melting point should be between 115 and 130°F. Petrolatum of Grade O, used as a softener in rubber, is a pale yellow odorless semisolid of specific gravity of 0.84 and melting point of 115 to 118°F. Sherolatum is petrolatum of the Sherwood Petroleum Company, Inc.

**Petroleum.** A heavy liquid, inflammable, mineral oil stored under the surface of the earth, and probably of ancient marine animal origin. It consists chiefly of carbon and hydrogen in the form of hydrocarbons, including most of the liquids of the paraffin series, $C_5H_{12}$ to $C_{16}H_{34}$, together with some of the gases, $CH_4$ to $C_4H_{10}$, and most of the solids of the series from $C_{17}H_{36}$ to $C_{27}H_{56}$. It also contains hydrocarbons of other series; the residue contains sulphur, nitrogen, and oxygen. Petroleums from different localities differ in composition, but tests of oils from all parts of the world give the limits as 83 to 87 per cent of carbon, 11 to 14 hydrogen, with sulphur, nitrogen, and oxygen in amounts from traces to 3 per cent. Mexican and Texan oils are high in sulphur. The crude oil is split by distillation into naphtha, gasoline, kerosene, lubricating oils, paraffin, and asphalt. It may also be split by cracking, that is, by subjecting to violent heating in the absence of air. This process yields a higher proportion of volatile products because of the breaking down of the more complex molecules by the high heat. Liquefied petroleum gases, including Propane, Butane, Pentane, or mixtures, are marketed under pressure in steel cylinders as Bottled gas. Propane, $CH_3CH_2CH_3$, is used in cook stoves. Butane,

which has an additional $CH_2$ group, is used to enrich illuminating and heating gas. Propane and butane gases have heating values from 2,800 to 3,000 B.t.u. per cu. ft. Liquid gas is also used for internal-combustion engines, as a solvent, and in the chemical industries as a reacting agent. Pyrogen is the trade name of a gas obtained during the process of recovering gasoline from natural gas. It is marketed in cylinders for use in flame cutting torches. Road oil, used on dirt roads, is a heavy residue oil from the petroleum refineries.

Petroleum from Baku was used from ancient times for lighting purposes, and the Bolivian oil was used in the sixteenth century for burning. The first commercial wells in the United states were opened in 1859 at Titusville, Pa. The chief production of petroleum is in Mexico, United States, Russia, Rumania, Asia Minor, Peru, and northern South America, but large reserves exist in many other places. See also Gasoline, Paraffin, Benzine, Fuel oil, Lubricating oil.

**Petroleum coke.** The final residue of the distillation of petroleum. It forms about 5 per cent, by weight, of the crude oil. After removing from the bottom of the still it is broken up and marketed as chipped and unchipped. The chipped coke has the brown sand and impurity crust removed. Petroleum coke contains about 99 per cent of pure carbon and is employed for making electric light carbons, carbon points, and carbons for various other purposes. Petroleum pitch is the final distillate before the coke, and is a black, tarry product, employed for roofing. Straw oil is an oil from the refining of petroleum or tar, used in coke making for the recovery of benzene, naphthalene, and toluene.

**Pewter.** A very old name for tin-lead alloys used for dishes and ornamental articles, but now referring to the use rather than to the composition of the alloy. Tin was the original base metal of the alloy, the ancient Roman pewter having about 70 per cent of tin and 30 of lead, although iron and other elements were present as impurities. Pewter, or Latten ware, of the sixteenth century contained as high as 90 per cent of tin. Pewter is now likely to contain zinc and antimony, and very

much less tin; when the proportion of tin is below about 65 per cent, the alloys are unsuited for vessels to contain food products, because of the separation of the poisonous lead. Antimony as an alloying product is also undesirable in food containers because of its poisonous nature; when the tin is low, antimony is needed to make the metal susceptible to polishing. "Best" pewter, for high-class articles, contains 100 parts of tin, 8 antimony, 2 bismuth, and 2 copper. "Triple" has 83 parts of tin, 17 antimony, or some lead to replace part of the antimony. Pewter should have a peculiar bluish-white luster when polished. It can be spun easily. Pewters containing much lead are dark in color and must be plated.

**Phenol.** Also known as Carbolic acid. A colorless to white crystalline substance of sweet odor, having the composition $C_6H_5OH$, obtained from the distillation of coal tar as a by-product of coke ovens, or is made synthetically by various methods. It is used industrially largely in the 82 to 92 per cent grades for the production of phenol resins used as molding materials. Phenol melts at about 43°C. and boils at 183°C.

The crystallization point is given as 40.41°C. The specific gravity is 1.066. It dissolves in most organic solvents. By melting the crystals and adding water, Liquid phenol is produced, which remains liquid at ordinary temperatures. Phenol has the unusual property of penetration of living tissues and forms a valuable antiseptic. It is thus used industrially in cutting oils and compounds and in tanneries.

**Phenol-formaldehyde resin.** A synthetic resin made by the reaction of phenol and formaldehyde, and employed as a molding material for the making of mechanical and electrical parts. Its high dielectric strength, resistance to acids and alkalies, hardness, and imperviousness to moisture, make it suitable for such uses as clock cases, electric switch parts, plating barrels, pump vanes, utensil handles, and ornamental parts. The reaction of the chemicals under heat and pressure produces a product physically resembling a resin but chemically dissimilar. This "polymerization" process is only partially carried out in the original resinoid, so that the material can be mixed with a

filler and molded to the desired form before the final "set" is given which makes the molded object inert to further chemical action.

The reaction was known as early as 1872 but was not utilized commercially until much later. A condensation product of 50 parts of phenol and 30 parts of 40 per cent formaldehyde made under English patent of 1905, was called Resinite, and was originally offered as a substitute for celluloid. Various modifications were made by other inventors. Redmanol was one of the first of the American products by the Bakelite Corporation. Juvelite was made in Germany by condensing the phenol and formaldehyde with the aid of mineral acids, and Laccain was made under an English patent by using organic acids as catalysts. A Russian phenol resin, under the name of Karbolite, employs approximately an equal amount of Naphtha-sulphonic acid, $C_{20}H_{20}SO_3H$, with the formaldehyde. It can be molded at a lower temperature.

Phenol-formaldehyde resins are transparent, brittle, soluble in alcohols, but insoluble in water, turpentine, or benzol. They are usually mixed with wood flour or other filler, which makes them less expensive and also more pliable and resistant to fracture. They can be easily dyed to any color, or pigments can be incorporated. The tensile strength of the resinoid is about 7,000 lb. per sq. in. and the specific gravity is 1.27; in the molded product the strength is much higher depending upon the type and quantity of filler employed. Wood flour-filled material is usually supplied in the form of dry, granular powder for molding. The molded material will not melt at any temperature, but begins to char at about 570°F. It is highly resistant to acids, oils, water, and alkalies. The molding is usually done at 350°F. and 2,000 lb. per sq. in. pressure. For ordinary molding wood flour is the common filler, but where heat resistance and greater hardness are desired asbestos, mica, or other mineral fillers are used.

The molded article takes the high finish of the dies. The specific gravity with wood filler is 1.34 to 1.52, tensile strength 6,000 to 11,000 lb. per sq. in., compressive strength 25,000 to 36,000 lb. per sq. in., and dielectric strength 300 to 500 volts

per mil. With mineral fillers the specific gravity is higher, the resistance is greater, the strength is lower.

Phenol resins may also be cast and then hardened by heating. The cast resins usually have a higher percentage of formaldehyde and do not have fillers. They are poured in sirupy state in lead molds and hardened in a slow oven. Crystallin, of the Crystallin Products Corporation, and Phenalin, of E. I. du Pont de Nemours & Company, Inc., are cast plastics. Catalin, of the American Catalin Corporation, is a cast phenol plastic made under the Dr. Fritz Pollack patents. Prystal is the name of water-clear Catalin, and Bois glacé is Catalin-coated wood for desk tops. Fiberlon is a cast phenol plastic of the Fiberloid Corporation. Tego resin film is a cast phenol resin cut into thin sheets to be interlined with veneers of wood and hot-pressed to make a strong and waterproof plywood. It is a product of the Resinous Products & Chemical Company, Inc. Marblette is a cast phenolic resin of the Marblette Corporation.

The Laminated plastics are made with paper, linen, or canvas. The kraft paper usually has a 35-per cent impregnation of the resin. Rag paper, linen, and canvas bases have higher impregnations. Rods are made by machining from the molded sheets, which gives parallel cords, or by winding sheet stock on a wire and molding when the wire is withdrawn. Bakelite laminated has a specific gravity of 1.32 to 1.41, hardness of 30 to 40 Brinell, compressive strength of 30,000 to 43,000 lb. per sq. in., flatwise, tensile strength of 8,500 to 24,000 lb. per sq. in., and dielectric strength of 400 to 900 volts per mil. The fabric-base materials have the highest physical properties. All the laminated products can be machined. Spauldite is a laminated material of the Spaulding Fibre Company, Inc. The paper-base materials for insulating purposes are made in sheets down to 1/64 in. in thickness. Dilecto is a laminated material of the Continental-Diamond Fibre Company. Graphite Dilecto, for bearings and thrust washers, has graphite impregnated in the sheets.

The phenol-formaldehyde resins are sold under many trade names such as Bakelite, of the Bakelite Corporation, and Durez, of the General Plastics Corporation, and many in turn are marketed under other trade names by the molders. Resinox,

of the Resinox Corporation, Makalot, of the Makalot Corporation, Colasta, of the Colasta Corporation, Reynolite, of the Cutler-Hammer, Inc., Indur, of the Reilly Tar & Chemical Corporation, are names for molded products, powders, and laminating varnishes. Amberol, of the Resinous Products & Chemical Company, Inc., is a phenol-formaldehyde resin for use in varnishes. Amberlite, of the same company, is a solution of the resin for laminating.

Rockite is a phenol plastic marketed in powder form by F. A. Hughes & Company, Ltd. Other English phenol resins are Tufnol, of Ellison Insulations, Ltd., Dekorit and Leukorit, of Uhlhorn Bros. Some German molding resins are Futurit, Resistan, Faturan, and Herolith.

The materials known as Micarta, of the Westinghouse Electric & Manufacturing Company, used for gears and electrical parts, Textolite, of the General Electric Company, Phenolite, of the National Vulcanized Fibre Company, and Formica, of the Formica Insulation Company, are Bakelite laminated, although molders and producers of laminated products do not usually confine themselves to one type of resin, and the same trade name may also indicate other synthetic resins. The variegated designs in Micarta and Formica panels are made by placing the design on paper or fabric as the outside lamination. Formica is also produced with asbestos paper and cloth bases. Fabroc is Bakelite combined with asbestos. Tenazit is the name of Textolite material produced in Germany. Celeron is the name of a group of laminated plastics of the Continental-Diamond Fibre Company. Cellanite, of this company, is a nonphenolic laminated plastic. Synthane is a laminated phenol material of the Synthane Corporation. Haveg, of the Haveg Corporation, is a phenol resin containing asbestos fibers. It is acid resistant and heat resistant to temperatures up to 265°F. One grade of Phenolite has an asbestos paper base. It has lower tensile strength but very high compressive strength.

The formaldehyde may be replaced in some products to make similar molding materials with somewhat different characteristics, such as Phenol-furfural and Phenol-hexamine resins. Acrolite is the trade name of a dark-colored resin made

by the action of phenol on glycerol. To give greater flexibility to the phenol resins so that they may be sheared or punched, tung oil, ester gum, or some other material may be added with the filler. Phenol resins are used in liquid form for cements, waterproof coatings, and as binders for abrasive wheels. For adhesives the resins are plasticised with gums or natural resins and dissolved in a solvent. Synthetic amber is a phenol resin made more pliable with glycerol or a plasticiser.

**Phonolite.** Also known as Clinkstone. An aluminum-potassium-silicate mineral used in the production of bottle glass, and in Germany for the production of aluminum. Phonolite varies greatly in composition, the best of the Eifel Mountains mineral containing 20 to 23 per cent of alumina, 7 to 9 per cent of $K_2O$, 6 to 8 of $Na_2O$, and 50 to 52 per cent of silica. A variety of this mineral, Nepheline, from the Kola Peninsula, is used in Russia to produce aluminum, with soda and potash as by-products. Agalmatolite, a name derived from the Greek words meaning Image stone, is the massive form of phonolite from which the Chinese carve figures and bas-reliefs. It has a soft greasy feel, and varies in color. See Pinite.

**Phosgene.** The common name for Carbonyl chloride, a colorless, extremely poisonous gas of the composition $COCl_2$, made by the action of chlorine on carbon monoxide. It is compressed into a liquid in shells and bombs for use as a lethal poison in chemical warfare. It is also known as D-stoff by the Germans. One part in 10,000 parts of air is fatal, but it is nonpersistent and difficult to obtain a concentration. It has a delayed action on the heart. When chloroform is exposed to light and air, it decomposes and forms phosgene. It was discovered by Davy in 1811 and was given the name "phosgene," meaning produced by light. Phosgene liquefies at ·8.2°C., and solidifies at −118°C. The specific gravity is 1.432 at 0°C. It is soluble in benzene, toluene, and other hydrocarbons. It is decomposed by water. The odor is like that of musty hay. Phosgene was known as Collongite by the French.

**Phosphor bronze.** Originally called Steel bronze when first produced in Austria. A bronze deoxidized by the addition of

phosphorus to the molten metal. It may or may not contain residual phosphorus in the final state. Ordinary bronze frequently contains cuprous oxide formed by the oxidation of the copper during fusion. By the addition of phosphorus, which is a powerful reducing agent, a complete reduction of the oxide takes place, and the resulting bronze has higher strength. Phosphor bronze is not usually a special alloy but is a deoxidized bronze, and all grades of bronze can be converted into it. But when there is residual phosphorus in the metal, the bronze is harder. Phosphor-bronze casting metals for bearings usually contain lead. A.S.T.M. Grade B phosphor bronze has 4.0 to 5.5 per cent of tin, 2.5 to 4 lead, and 0.03 to 0.25 phosphorus. A foundry alloy known as Standard phosphor bronze contains about 80 per cent of copper, 10 tin, and 10 lead, with about 0.25 phosphorus. When chill-cast, it is fine grained and has a tensile strength up to 33,000 lb. per sq. in., Brinell hardness of 65, and weight of 0.325 lb. per cu. in. One large automotive company lists this metal as Phosphor casting bronze. The phosphor-bronze ingot metal of this composition marketed by H. Kramer & Company contains 0.50 to 1 per cent of phosphorus, part of which is absorbed in the melting and casting. The usual residual phosphorus is 0.25 per cent.

Anaconda phosphor bronze, a wrought metal marketed by the American Brass Company, is in grades containing from 5 to 10 per cent of tin and 90 to 95 copper. The 90–10 grade for springs has high resistance to fatigue. Seymour phosphor bronze, of the Seymour Mfg. Company, used for springs, has 95 per cent of copper, 4.75 tin, and 0.25 phosphorus. Corvic bronze, of the Chase Brass & Copper Company, has 98.5 per cent of copper, 1.5 tin, and 0.30 phosphorus. The tensile strength of the spring material is 95,000 lb. per sq. in., and the electrical conductivity is 42 per cent that of copper. Anaconda special phosphorus bronze, used for screw-machine parts, contains 88 per cent copper, 4 tin, 4 zinc, and 4 lead. It is free cutting and has high strength. Hard-drawn phosphor-bronze wire may have a tensile strength exceeding 120,000 lb. per sq. in. White phosphor bronze, for bearings, contains 72 per cent lead, 12 antimony, 15 phosphor tin, and 1 copper. The original Steel bronze made at

the Royal Arsenal in Vienna was a 92-8 bronze deoxidized with phosphorus and cast in an iron mold.

**Phosphor copper.** An alloy of phosphorus and copper, used instead of pure phosphorus for deoxidizing brass and bronze alloys, and for adding phosphorus in making phosphor bronze. It comes in 5, 10 and 15 per cent grades and is added directly to the molten metal. It serves as a powerful deoxidizer, and the phosphorus also hardens the bronze. Phosphor copper is made by forcing cakes of phosphorus into molten copper and holding under until the reaction ceases. Phosphorus is soluble in copper up to 8.27 per cent, forming $Cu_3P$, which has a melting point of 707°C. A 10 per cent phosphor copper melts at 850°C., and a 15 per cent at 1022°C. Alloys richer than 15 per cent are unstable. Phosphor copper is marketed in notched slabs or in shot. In Germany Phosphor zinc is used as a substitute to conserve copper. Metallophos is a name for German phosphor zinc containing 20 to 30 per cent of phosphorus. The name phosphor copper is also applied to commercial copper deoxidized with phosphorus and retaining up to 0.50 per cent of phosphorus. The electrical conductivity is reduced about 30 per cent, but the copper is hardened and strengthened. See also Phosphorized copper.

**Phosphor tin.** A master alloy of tin and phosphorus used for adding to molten bronze in the making of phosphor bronze. It usually contains up to 5 per cent of phosphorus and should not contain lead. It has an appearance like antimony, with large glittering crystals, and is marketed in slabs. Federal specifications call for 3.5 per cent of phosphorus, with not over 0.50 per cent of impurities.

**Phosphorus.** A nonmetallic element, symbol P, widely diffused in nature, and found in many rock materials, in ores, in the soil, and in parts of animal organisms. Commercial phosphorus is obtained from phosphate rock by reduction in the electric furnace with carbon, or from bones by burning and treating with sulphuric acid. Phosphate rock occurs in the form of land pebbles and as hard rock. It is plentiful in the Bone Valley area of

Florida, and also comes from Tennessee and some other states. It is a Calcium phosphate high in $P_2O_5$. The mineral Apatite, from Virginia and Brazil, is also a source of phosphorus, containing up to 20 per cent $P_2O_5$, with iron oxide and lime.

Phosphorus is highly important in foundry work because of its property of combining and greatly modifying the characteristics of metals, and because of its deoxidizing power, especially in nonferrous metals. It is added to the latter in the form of phosphor-copper or phosphor-tin. There are two forms of phosphorus, yellow and red. The former, also called White phosphorus, $P_4$, is a light-yellow waxlike solid, phosphorescent in the dark and exceedingly poisonous. Its specific gravity is 1.83 and melting point 44°C. It is used for smoke screens in warfare and for rat poisons and matches. Red phosphorus is a reddish-brown amorphous powder, having a specific gravity of 2.296 and a melting point of 725°C. Both forms ignite easily. Phosphorus sulphide, $P_4S_3$, may be used instead of white phosphorus in making matches.

**Piano wire.** A generally accepted name for a cold-drawn steel wire of high quality, intended for piano strings, but also used for many other purposes in industry. Much of the piano wire used in the United States is drawn from Swedish billets or rods. Piano wires range in diameter from 0.03 in. to 0.065 in. Starting with No. 7 rod there may be as high as 40 draws before the finished wire is produced. The tensile strength of high-grade piano wire is from 350,000 to 400,000 lb. per sq. inch.

**Piassava.** Also called Para-grass and Monkey-grass. A coarse, stiff, and elastic fiber obtained from a species of palm tree, *Leopoldinia piassaba*, of Brazil, used for making brushes and brooms. The plant has long beards of bristlelike fibers, which are combed out and cut off the young plants. These fibers sometimes reach a length of 4 feet. The long, finer fibers are made into cordage, and the coarser ones are used for brushes. Piassaba is very resistant to water. The fiber for brush manufacture is separated into three classes, the heavy fibers being known as Bass, the medium as Bassine, and the fine as Palmyra. The bass is used for heavy floor sweeps. Piassava is spelled also Piassaba.

**Pickling acids.** Acids used for pickling, or cleaning castings or metal articles. The common pickling bath for iron and steel is composed of a solution of sulphuric acid and water, 1 part acid to from 5 to 10 parts of water being used. This acid attacks the metal and cleans it of the oxides and sand by loosening them. For pickling scale from stainless steels a 25 per cent cold solution of hydrochloric or sulphuric acid is used. Hydrofluoric acid solutions are sometimes used for pickling iron castings. This acid attacks and dissolves away the sand itself. For cleaning brass a mixture of sulphuric acid and nitric acid, in the ratio 3:2, is used. Since all of these acids form salts rapidly by the chemical action with the metal, they must be renewed with frequent additions of fresh acid. The temperature of most pickling solutions is from 140 to 180°F. An increase of 20°F. will double the rate of pickling. Acid brittleness after pickling is due to the absorption of hydrogen when the acid acts on iron, and is reduced by shortening the pickling time. Inhibitors are chemicals added to reduce the time of pickling by permitting higher temperatures and stronger solutions without hydrogen absorption. Phosphoric acid, $H_3PO_4$, is employed in hot solution as a dip bath for steel parts to be finished to a rough or etched surface. A basic iron phosphate coating is produced on the steel, which is resistant to corrosion and gives a rough base for the finish. Coslettised steel is steel rust-proofed by dipping in a hot solution of iron phosphate and phosphoric acid. An American patented process producing Parkerized steel is done with iron and manganese phosphates. Granodised steel is produced with zinc phosphate.

**Picric acid.** A high explosive, known also as Trinitrophenol, and as Melinite by the French. The British explosive Lyddite, and the Japanese explosive Schimose are both cast picric acid. It is a lemon-yellow crystalline solid of the composition $C_6H_2(OH)(NO_2)_3$, slightly soluble in water and soluble in alcohol and in benzene. It has a persistent bitter taste. Its property of coloring is utilized as a dyestuff. Due to the fact that picric acid forms dangerous sensitive salts with metals it is not used in the United States as an explosive, but as a raw product in the manufacture of ammonium picrate. Picric acid is one of the most powerful of explosives, being exceeded only by tetryl and

trinitro-aniline. Picric acid melts at 248°F. It is made by treating phenol with sulphuric and nitric acids, or can be made directly from benzene. When used in shells, the picric acid must be kept from contact with the metal by the use of lacquer. Cressylite is a mixture of picric acid and trinitrocresol, used by the French as a shell filler because of its lower melting point.

**Pig iron.** The iron produced from the first smelting of the ore. The melt of the blast furnace is run off into rectangular molds forming, when cold, ingots called pigs. Pig iron contains small percentages of silicon, sulphur, manganese, and phosphorus, besides carbon. It is useful only for re-smelting to make cast iron or wrought iron. Pig iron is either sand-cast or machine-cast. The former has sand adhering and fused into the surface, giving more slag in the melting. Machine-cast is cast in steel forms, has a fine-grained chilled structure, with lower melting point. Pig irons are classified as Bessemer or non-Bessemer, according to whether the phosphorus content is below or above 0.10 per cent.

There are 6 general grades of pig iron as follows: Low phosphorus, with less than 0.03 per cent, used for making steel for steel castings and for crucible steel making; Bessemer, with less than 0.10 per cent of phosphorus, used for Bessemer steel and for acid open-hearth steel; Malleable, with less than 0.20 per cent, used for making malleable iron; Foundry, with from 0.5 to 1 per cent, for cast iron; Basic, with less than 1 per cent, and low silicon, less than 1 per cent, for basic open-hearth steel; and basic Bessemer, with from 2 to 3 per cent, used for making steel by the basic Bessemer process employed in England.

About two-thirds of all pig iron produced in the United States is basic. Since silicon is likely to dissolve the basic furnace lining, it is kept as low as possible, 0.70 to 0.90 per cent, with sulphur not usually over 0.095 per cent. Pig irons are also specified on the content of other elements, especially sulphur. The sulphur may be from 0.04 to 0.10 per cent, but high-sulphur pig iron cannot be used for the best castings. The manganese content is usually from 0.60 to 1.0 per cent. Most of the iron for steel making is now not cast but is carried directly to the steel mill in car

ladles. It is called Direct metal. Foundry pig iron is graded by the silicon content, No. 1 having from 2.5 to 3 per cent, and No. 3 from 1.5 to 2.0 per cent of silicon. Puddling iron is a grade of pig iron used for making wrought or puddled iron in a puddling furnace. A requirement is that the silicon be low, with manganese 0.5 to 1 per cent. See also Charcoal iron and Mayari iron.

**Pigment.** A substance, usually earthy or clayey, which when mixed with oil or other solvent forms a paint. Pigments usually give body as well as color to the paint. The hiding power is measured by comparison tests when in the form of a mixed paint. See Paint. A pigment is distinct from a filler in that it must retain its opacity when wet. White powdered quartz, used sometimes as a filler, is not a good pigment as it becomes glassy when wet. Fillers which retain their opacity are called Extenders, or Auxiliary pigments. Pigments are mostly of mineral origin, the vegetable pigments such as logwood, and the animal pigments such as cochineal, being ordinarily classified as dyestuffs. Bone black, however, is an example of an animal pigment, and vine black is typical vegetable pigment. Pigments are also produced by dyeing clays with aniline dyestuffs. Natural pigments include ochre, umber, ground shale, hematite, and sienna. White lead, bismuth oxychloride, blanc fixe, ultramarine, and antimony red are examples of mineral pigments. Orange pigments, from yellow to brilliant red, with high tinting strength and great fastness, are made with mixtures of Lead chromate, $PbCrO_4$, Lead molybdate, $PbMoO_4$, and Lead sulphate, $PbSO_4$.

The most important yellow is Chrome yellow, but it fades easily. Yellow ochre is inferior as a color but is more durable. Cadmium yellow is permanent and brilliant but expensive. It is Cadmium sulphide, CdS, used for either oil or water paints. The most important green is Chrome green, which is chrome yellow mixed with Prussian blue. The latter is ferrocyanide of iron, giving a good color but not permanence. Ultramarine is the most important blue. Cobalt blue is considered a good color but is expensive. Vermilion is mercury sulphide, which gives a fine color and is permanent, but it is expensive. High-grade blacks are usually lampblack, bone black, and ivory black, but may be

adulterated with graphite. Spanish black is a name used in old texts for the black pigment made by burning cork. It is light and of soft texture. Mineral black, or Slate black, is made by grinding black slate. Pigments should be ground fine enough so that all of the powder will pass through a 325-mesh screen. Pearl essence, used in lacquers for automobile finishes and in synthetic molding materials, is a motley-silver material extracted from the skins of several varieties of fish. It gives lacquers high luminosity and iridescence. See also Lead pigments, Ferric oxide, Vermilion red, Lithopone, Zinc white.

**Pine.** The wood of coniferous trees of the genus *Pinus*, of which there are 37 species in the United States. The White pine, *P. strobus*, grows widely in Canada and in the Northeastern United States. The trees are 80 to 100 ft. high, with trunks 3 to 9 ft. in diameter. The wood is soft, white, straight-grained, and free from rosin. It is the chief wood for patternmaking and is also extensively used for cabinetwork and general carpentry. Yellow pine is a name for the wood of the Longleaf (Longstraw) pine tree, *P. palustris*, of the Southeastern states, and Shortleaf pine, *P. echinata*, of the Southeast and Middle Western states. The leaves, called needles or straws, of the longleaf pine are up to 18 in. in length. The Longleaf pine tree furnishes the best grades of yellow pine and also is the chief source of turpentine. It is also called Georgia pine, Southern pine, Hard pine, and Hill pine. Slash pine, also known as Cuban pine and Swamp pine, from the tree *P. heterophylla*, or *P. caribaea* (Caribbean pine), growing along the Southern coasts of the United States and in the Caribbean countries, is also a yellow pine. It is one of the most rapidly growing forest trees in the United States and produces one of the heaviest, hardest, and strongest of all the conifer or "soft woods." Slash pine is next to longleaf line as a source of turpentine and resin. As heartwood does not develop until the tree is 20 or more years old, slash pine forms a valuable source of paper pulp. The term Arkansas pine in the lumber trade includes mixtures of shortleaf, longleaf, slash, loblolly, and pond pines.

Western yellow pine is from the tree *P. ponderosa* of the Mountain states. The tree grows to a height of 175 ft. and a

diameter of 6 ft. It is also a source of turpentine and rosin. A similar western pine, Jeffrey pine, *P. jeffreyi*, contains heptane instead of turpentine in the oleoresin. Loblolly pine, *P. taeda*, is called North Carolina pine. Pitch pine is the Pond pine, *P. rigida*, of the Southern states, but all yellow pines are called pitch pine in the export trade. Norway pine, of the North-central states, is *P. resinosa*. The yellow pines are harder and more difficult to work than white pine. They are resinous and more durable. They also take a better polish and show a more figured grain. They are valued for flooring and for general construction. White pine has a specific gravity, kiln-dried, of 0.38 and compressive strength perpendicular to the grain of 780 lb. per sq. in.; Western white pine, *P. monticola*, has a specific gravity of 0.42 and a compressive strength of 750 lb. per sq. in. Deal is a European name for the wood of the tree *P. sylvestris*, also known as Danzig pine, Baltic pine, Scotch fir, Scotch pine, and Northern pine. Kauri pine is a strong, durable, straight-grained, yellowish wood from the tree *Dammara australis*, of New Zealand. See also Sugar pine.

**Pine oil.** A turpentine oil obtained from the wood of the *Pinus palustris*, or longleaf pine, in the steam extraction of wood turpentine. It is used as a cold solvent for varnish gums and for nitrocellulose lacquers. In paints and varnishes it aids dispersion of metallic pigments and improves the flow. It is also used in metal polishes and in liquid and powder scrubbing soaps, as the oil is a powerful solvent of dirt and grease. When free from water, pine oil has a yellowish color but is water-white when it contains dissolved water. It has an aromatic, characteristic odor, and is distinct from the pine oils distilled from pine leaves and needles and used in medicine. The distillate of the gum of the Jeffrey and Digger pines of California, called Abietine in medicine, contains 96 per cent heptane and is used as a cleaning agent and insecticide, and as a constituent of standard gasolines for measuring detonation of engines. Yarmor is the trade name of the Hercules Powder Company for highly refined pine oil used in soaps, paper coating, marine paints, and as a wetting agent. Hercosol is a solvent made from pine oil by the same company. Pine oil is obtained mainly from old trunks and branches, and is a product formed by hydrolysis.

**Plane wood.** The wood of the plane tree, *Platanus orientalis*, native to Europe, and *P. occidentalis*, of North America. The latter species is also called Buttonwood and buttonball. It is a yellowish, compact wood with a fine, open grain. The weight is about 40 lb. per cu. ft. It resembles maple and gives a beautiful grain when quartered. It is employed in cabinetwork.

**Plaster board.** Sheets or slabs consisting of gypsum or some other incombustible substance intimately mixed with about 15 per cent of fiber, and employed for ceilings, partitions, or walls. It may also be made up of a core of gypsum surfaced with paper or fibrous material, and designed to be coated with gypsum after being erected in place. Standard specifications for gypsum boards call for thickness of ¼, 5⁄16, ⅜, and ½ in., with usual surface dimensions of 24 by 32 in. The weight of gypsum plaster board ¼ in. thick is 1,200 lb. per 1,000 sq. ft. The term "Plaster" alone usually refers to cements or plastering materials made of gypsum, but spent fuller's earth is employed in making calcium plaster. It has greater workability and covering capacity than ordinary plaster, and is more water-resistant.

**Plaster of paris.** Also called Molding plaster. A soft white powder which, when mixed with water, forms a paste that can be molded and will harden into a solid mass. It is used for making casts and in cements and plasters. It is made by heating gypsum at about 110°C., forming the hemi-hydrate $2CaSO_4 \cdot H_2O$. This product constitutes plaster of paris, which when mixed with water again forms the hydrated sulphate that will solidify and set due to interlocking crystallization. Theoretically, 18 per cent of water is needed for mixing, but actually more is necessary. An excess of water, however, makes the product slow setting and weakens it; insufficient water causes cracking. Lime water, glue water, or mucilage in water is frequently used. Owing to its solubility in water plaster of paris cannot be used for outside work. The usual time of setting is 2 to 6 hr. Plaster of paris is the basis of all gypsum plasters. Neat plaster, for walls, is plaster without sand.

**Plastic bronze.** A name applied by makers of bearing bronzes to copper alloys that are "plastic" enough to assume the

shape of the shaft and make a good bearing by "running in." These bronzes have a variety of compositions, but the plasticity is always obtained by the addition of lead, which in turn weakens the bearing. In some cases the lead content is so high, and the tin content so low that the alloy is not a bronze. These copper-lead alloys are referred to as Red metals. The Plastic bronze ingot marketed by one large foundry for journal bearings contains 65 to 75 per cent of copper, 5 to 7 tin, and the balance lead. Semiplastic bronze usually contains above 75 per cent of copper and not more than 15 of lead. A.S.T.M. alloy No. 7 has about 10 per cent of lead, 10 tin, 1 zinc, 1 antimony, and the balance copper. The compressive strength is 12,500 lb. per sq. in. See High-lead bronze.

**Plastic wood.** Wood cellulose dissolved in ether or other solvent, used for filling or for building up small sections. It hardens on evaporation of the solvent and can be cut, polished, and painted. It may also consist of cellulose nitrate and a plasticising agent dissolved in acetone or ethyl acetate and mixed with wood flour. It shrinks greatly in setting.

**Plate glass.** Any glass that has been cast or rolled into a sheet, and then ground and polished. But the good grades of plate glass are, next to optical glass, the most carefully prepared and the most perfect of all the commercial glasses. It generally contains slightly less calcium oxide and slightly more sodium oxide than window glass. A typical batch formula is sand, $SiO_2$, 1,000 lb.; limestone, $CaO$, 320 lb.; soda ash, $Na_2O$, 310 lb.; salt cake, 65 lb.; and charcoal 3 lb. Small quantities of iron and aluminum oxides are also always present as impurities. The glass is melted in open pots. The melting and refining take about 20 hr., and the glass is then poured on the casting table at 1000°C. The roller is drawn over the plastic glass. After annealing, the sheets are set in plaster of paris on a circular rotating table and ground with iron blocks and sand. Herculite is a glass of the Pittsburgh Plate Glass Company which will withstand temperatures up to 650°F. without cracking.

**Platinoid.** An alloy employed for jewelry and ornamental objects. It is a nickel-silver containing 2 per cent of tungsten

added to the melt in the form of phosphor-tungsten. Platinoid is a hard, white metal that retains its luster very well. The name Platinoid is also an English trade name for a Tungsten bronze, or alloy of copper and tungsten, used for valve seats.

**Platinum.** A whitish-gray metal, symbol Pt. It is more ductile than silver, gold, or copper, and is heavier than gold. The melting point is 3190°F., and the specific gravity is 21.40. The hardness of the annealed metal is 37 Brinell and tensile strength 42,000 lb. per sq. in.; when hard-rolled the Brinell hardness is 90 and tensile strength 54,000 lb. per sq. in. It is very ductile and malleable. It resists the action of alkalies and most acids, dissolving only in hot aqua regia. Platinum occurs native in small flat grains or pebbles, usually alloyed with iridium, rhodium, palladium, osmium, and ruthenium. The largest nugget ever found came from South America and weighed 2 lb. It is also found in the mineral sperrylite. The chief sources are Russia and Colombia, with smaller amounts from Alaska, Canada, and South Africa. The world production is about 170,000 oz. annually, of which more than half comes from Russia. The Russian platinum is refined locally, and is from 99.80 to 99.90 per cent pure, with 0.05 to 0.10 per cent of iridium.

Platinum is employed for electric contact points for currents less than 4 amp., for resistance wires, thermocouple wires, standard weights, and for vessels for laboratory use. It is also used in jewelry. It is too soft for use alone, however, and is almost always alloyed with harder metals of the same group, such as iridium and osmium. An important use of the metal is in the form of gauze as a catalyst in chemical reactions, usually alloyed with 10 per cent of rhodium, but for this purpose vanadium and rhodium can be substituted. Platinum is sold by the troy ounce, a cu. in. of the metal weighing 11.28 troy oz.

**Platinum-iridium alloys.** The most widely used of the platinum alloys. They are employed for instruments, magneto contacts, and jewelry. The alloys are hard and tough and are noncorrosive. An alloy of 5 per cent iridium and 95 per cent of platinum, when hard-worked, has a Brinell hardness of 170; an alloy containing 30 per cent of iridium has a hardness of 400.

The 5 and 10 per cent alloys are used for jewelry manuracture; the 25 and 30 per cent alloys are employed for making surgical instruments. An alloy of 80 per cent platinum and 20 iridium is used for magneto contact points. The addition of iridium does not alter the color of the platinum. The 5 per cent alloy dissolves readily in aqua regia; the 30 per cent alloy dissolves slowly.

**Plush.** A general name for fabrics woven of cotton, silk, linen, or wool, having a pile deeper than that of velvet. It is used for upholstery. Originally the pile of plush consisted of mohair or worsted yarns, but there is now no distinction except in the length of the pile. Upholstery plush is sometimes made in brocade designs by burning the pile with rollers to form a lower background. Plush is also dyed and curled to imitate furs.

**Plywood.** A laminated wood made up of one or more sheets of soft wood with thin sheets of more expensive hardwood glued on the outside. The outside sheets are known as Veneer, but this term is also applied to very thin wood sheets for other purposes. Laminated woods were originally developed to increase artistic appeal of furniture by gluing figured woods to ordinary woods with the veneers matched to give artistic effects. Plywood is always built up in odd numbers of layers, and the grains of successive layers are set at right angles. This arrangement gives tensile and compressive strength in all directions and also symmetrical shrinkage stresses. The strength depends largely on the glue. A blood-albumin glue used by one plywood manufacturer has a strength of 370 lb. per sq. in., dry shear, and 240 in wet shear after soaking for 24 hr. Plywood bonded with synthetic plastics is strong and waterproof. See Tego resin.

For construction purposes, where plywood is employed because of its unit strength and nonwarping characteristics, the plies may be of a single type of wood without a hardwood face. The Douglas Fir Plywood Association sets up four classes of construction plywood under general trade names. Plywall is plywood in wallboard grade; Plypanel is plywood in three standard grades for general uses; Plyscord is unsanded plywood with defects plugged and patched on one side; Plyform is plywood in a grade for use in concrete forms.

Plywood may have one thick board of cheap wood and two of hardwood, or it may have a large number of thin layers. Basswood, yellow poplar, Spanish cedar, fir and pine are used for cores. Ash, mahogany, walnut, or any of the expensive woods are used for the outside sheets. The tensile strength of a commercial white ash 3-ply plywood parallel to the grain of the faces is about 6,200 lb. per sq. in., that of a mahogany 6,400 lb., and a walnut plywood 8,200 lb. per sq. in. Mahogany plywood comes in large sheets with thickness of 1/16 in. to 1/4 in. Armorply is a plywood marketed by the United States Plywood Company, Inc. Flexwood, of this company, consists of very thin sheets of veneer glued under heat and pressure to cotton sheeting, used as an ornamental covering for walls. Woven veneer is a paneling made of thin strips of mahogany or other fine wood woven in patterns and pressed between sheets of transparent cellulose acetate. Parkwood is a veneer of this type marketed in sheets by the Parkwood Corporation. Pregwood, of the Formica Insulation Company, is made up of wood impregnated with phenolic resin and cured into a hard sheet. Algonite, of the United States Plywood Corporation is Masonite faced with fancy veneers.

Plywood, or Paneling board, may also be made with metal or fabric plies. Plymax is an English plywood produced by Venesta, Ltd., consisting of thin sheets of aluminum mounted on a plywood backing. Plymetl, of the Haskelite Manufacturing Corporation, consists of a core of laminated wood with galvanized steel faces cemented to it. Aluminum-Plymetl has aluminum facings on Haskelite plywood. The metal-faced plywoods are strong and can be riveted. Met-L-Wood, of the Met-L-Wood Corporation, is made of two layers of light wood separated by sheet metal, with a fabric cemented to one side. It is used for automobile and truck sides, and has high strength in proportion to weight. Plywood in block form is sometimes used for making rolls, gears, die blocks, and pulleys. Sprucolite, of the Sprucolite Corporation, is such a material made from sheets of western spruce impregnated with a waterproof binder, laminated at right angles, and subjected to hydraulic pressure to make it dense and hard. The coefficient of friction is nearly 50 per cent higher than that of cast iron; the weight is about 35 per cent that of iron.

**Poison gases.** Substances employed in chemical warfare for disabling men, and in some cases used industrially as fumigants. They are all popularly called gases, but many are liquids or solids. They are classified into groups according to their main effect on the human system, but one gas may have several effects. They are grouped as follows: Lethal, intended to kill, such as phosgene; lachrymators, which affect the eyes, such as chloropicrin; vesicants, or skin blisterers, such as lewisite and mustard gas; sternutatory, which induce sneezing and force the removal of gas masks, such as diphenyl-chloroarsine; and camouflage, which are harmless, but cause soldiers to suffer the inconvenience of wearing gas masks and thus reduce their morale. Gases are also sometimes designated as casualty agents and harassing agents, and further subdivided into persistent and nonpersistent. A Systemic gas is one that interferes with one phase of the system, such as carbon monoxide which paralyzes the respiratory function of the blood. A Labyrinthic gas is one which affects an organ of the body, such as Dichlormethyl ether which affects the ears.

Effects of persistent gases, such as mustard, remain over the ground for as long as 7 days, but phosgene is quickly decomposed by dampness. Obscuring agents such as white phosphorus, and Toxic smokes, such as diphenyl-amino-chlorarsine, are also classed as war gases. Smoke screens are not intrinsically poisonous. The heavy mineral known as Amang, separated from tin ore, containing ilmenite and zircon, is used in smoke screens for ships. See Smoke agents, Titanium tetrachloride, Tetra-chlorethane. Hot pitch and oils were used in ancient warfare. See Greek fire. War gases are more destructive to morale than to life, as it is difficult to obtain a cloud of sufficient toxic power except with the highly persistent gases. See Lethal gases and Tear Gas.

**Polystyrene.** A synthetic resin used for molding, in lacquers, and for coatings, formed by the polymerization of monomeric Styrene, which is a colorless liquid of the composition $C_6H_5CH{:}CH_2$. The polymerized resin is a transparent solid with a tensile strength of 5,500 to 7,000 lb. per sq. in. and high dielectric strength. It is marketed in powder or pellet form to be

molded under heat and pressure like other synthetic resins. For molding, fillers may be added. Polystyrene is valued as an electrical insulator, and the films are used as cable wrapping. For coating purposes plasticizers are added to increase pliability. Victron, of the Naugatuck Chemical Company, and Styron, of the Dow Chemical Company, are clear transparent polystyrene resins highly resistant to acids and alkalies, and having high electrical resistance. This type of plastic is also used for the transparent dials on gages.

**Pontianak.** A gum from several species of the tree *Dyera*, of Borneo. The commercial pontianak is a grayish-white mass like burned lime, and contains 60 per cent of water, with only 10 to 25 per cent of rubberlike materials. It is used in the friction compounds employed for coating canvas transmission belting, and for mixing with gutta percha. Pontianak copal is copal from varieties of *Agathis* trees of Borneo. Its peculiar turpentinelike qualities come from the method of tapping. It is valued for varnishes. See Copal.

**Poplar.** The wood of several species of the tree *Populus*. The Black poplar, or English poplar, *P. nigra*, of Europe, is a large tree with blackish bark. The wood is yellowish white with a fine, open grain. It is soft and easy to work. The weight is about 35 lb. per cu. ft. It is used for paneling, inlaying, packing cases, carpentry, and paper pulp. Cottonwood is another species of poplar. See Cottonwood. Gray poplar is from the tree *P. canescens*, of Europe. The color of the wood is light yellow. It has a tough, close texture somewhat resembling that of maple. It is used for carpentry and flooring. The wood of the canary whitewood is called Virginia poplar, or simply poplar, but belongs to a different family of trees. See Canary whitewood. Aspen is also called poplar. See Aspen.

**Portland cement.** The best known and most generally useful of the construction cements. It is a bluish-gray powder obtained by finely grinding the clinker obtained by heating strongly an intimate mixture of calcareous and argillaceous materials. The chief raw material is a mixture of high-calcium lime-

stone and clay or shale. The mixture should be finely divided and contain about 75 per cent of calcium carbonate and the remainder largely aluminum silicate and free silica. Next in importance is the argillaceous limestone known as Cement rock, either alone or with high-calcium limestone. A mixture of blast-furnace slag and limestone is also used. In Pozzuolana portland cements highly siliceous materials are used, such as diatomite or pumicite, to give high strength and superior workability. The raw materials for portland cement are ground either wet or dry, and the clinker must be neither underburned nor overburned. The color of the cement is due to iron oxides. The calcined cement contains from 25 to 60 per cent of tricalcium silicate, from 7 to 44 per cent of dicalcium silicate, and about 10 per cent of tricalcium aluminate. Gypsum may be added to control the setting.

In the absence of impurities portland cement would be white, but neither the color nor the specific gravity is a test of quality. The specific gravity is at least 3.10. Good mortar cement is always ground very fine, with 98.5 per cent passing a 200-mesh screen.

The compressive strength of a portland cement when made into concrete will vary widely, depending upon the type and size of sand and stone mixture. In a good cement the initial set should not develop in less than 1 hr. Portland cement will set under water. The gradual increase in strength of cement is due to the hydration of the tricalcium aluminate and silicates. Portland cement for construction purposes is always used with sand. Non-staining cements are those free from perceptible amounts of iron oxide. White cement is from pure calcite limestone, such as found in eastern Pennsylvania. It is ground finer and used for better class work but the physical properties are similar to ordinary portland cement. High-speed cement usually contains high percentages of alumina and lime and will harden rapidly, but is more costly than ordinary grades. See Lumnite cement. Portland cement is sold in 94-lb. cloth or paper bags of 1 cu. ft. capacity, 4 to the barrel. See also Concrete, and Cement mortar.

Portland cement is also used for insulating and building blocks by mixing with materials other than sand. Careystone, of the Philip Carey Company, is made with portland cement mixed

with asbestos fibers and pressed into blocks, and into corrugated slabs used for roofing and siding. It is also made into sheathing and wallboard. Careycel is this material bonded to insulation board to form air cells.

**Port Orford cedar.** Known in England as Lawson cypress. The wood of the tree *Chamaecyparis lawsoniana*, of California and Oregon, also called White cedar and Oregon cedar. The wood is light yellow in color, straight grained, light in weight, and of moderate strength and hardness. It is somewhat gummy and difficult to plane smooth. It has an agreeable, aromatic odor and is durable. The logs are obtainable in great lengths and up to 12 ft. in diameter. It is used for doors, sash, matches, and general construction.

**Potash.** Also called Pearl ash. A white alkaline granular powder, which is a Potassium carbonate, $K_2CO_3$ or $K_2CO_3 \cdot H_2O$, used in soft soaps, for wool washing, and in glass manufacture. It is produced from natural deposits in Russia and Germany, and also produced from wood and plant ashes. The specific gravity of potash is 2.33 and melting point 909°C. Hartsalz, mined in the Carpathian Mountains and used for producing potash, is a mixture of sodium chloride, potassium chloride, and magnesium sulphate. It is also a source of magnesium.

**Potassium.** An elementary metal, symbol K, also known as Kalium. It is silvery white in color, but oxidizes rapidly in the air and must be kept submerged in ether or kerosene. It has a low melting point, 63.5°C. and a boiling point at 757°C. The specific gravity is 0.862. It is soluble in alcohol and in acids. It decomposes water with great violence. Potassium is obtained by the electrolysis of potassium chloride. It has no commercial applications, but potassium compounds are widely employed. Potassium hydride is used for the photosensitive deposit on the cathode of the photoelectric cell. It is extremely sensitive and will emit electrons under a flash so weak and so rapid as to be imperceptible to the eye. Potassium diphosphate, $KH_2PO_4$, a colorless, crystalline, or white powder soluble in water, is used as a lubricant for wool fibers to replace olive oil in spinning

wool. It has the advantages that it does not become rancid like oil and can be removed without scouring.

**Potassium chlorate.** Also known as Chlorate of potash and Potassium oxymuriate. A white crystalline powder, or lustrous crystalline substance of the composition $KClO_3$, employed in explosives, chiefly as a source of oxygen. It melts at 357°C. and decomposes at 400°C. with the rapid evolution of oxygen. It is odorless but has a slightly bitter saline taste. The specific gravity is 2.337. Potassium chlorate is not hygroscopic and does not alter on exposure to the air. It is, however, soluble in water but insoluble in alcohol. It imparts a violet color to the flame when used in pyrotechnic compositions. It is made by the electrolysis of potassium chloride solutions. See Sprengle explosives.

**Potassium chloride.** A colorless or white crystalline substance of the composition KCl, used for molten salt baths for the heat-treatment of steels. The specific gravity is 1.987. A bath composed of 3 parts of potassium chloride and 2 of barium chloride is used for hardening carbon-steel drills and other tools. Steel tools heated in this bath and quenched in a 3 per cent sulphuric acid solution have a very bright surface. A common bath is made up of potassium chloride and common salt and can be used for temperatures up to 900°C.

**Potassium cyanide.** A white amorphous or crystalline mass of the composition KCN, employed for carbonizing steel for casehardening and for electroplating. The specific gravity is 1.52, and it melts at about 1550°F. It is soluble in water and is extremely poisonous, giving off the deadly hydrocyanic acid gas. For cyaniding steel the latter is immersed in a bath of molten cyanide and then quenched in water, or the cyanide is rubbed on the red-hot steel. For this use, however, sodium cyanide is usually preferred, because of its lower cost and the higher content of CN in the latter. Potassium ferrocyanide, or Yellow prussiate of potash, can also be used for casehardening steel. It has the composition $K_4Fe(CN)_6$ and comes in yellow crystals or powder. The nitrogen as well as the carbon enters the steel to form the hard case. Commercial potassium cyanide is likely to contain a proportion of sodium cyanide.

**Potassium nitrate.** Also called Niter, and Saltpeter, although these usually refer to the native mineral. A substance of the composition $KNO_3$, used in explosives and for bluing steel. A mixture of 2 parts of potassium nitrate and 3 of sodium nitrate is used for steel tempering baths. The mixture melts at 250°C. Potassium nitrate is made by the action of potassium chloride on sodium nitrate, or Chile saltpeter. It occurs in colorless, prismatic crystals, or as a crystalline white powder. It has a sharp saline taste and is soluble in water. The specific gravity is 2.1 and melting point is 337°C. It is found in nature in limited quantities in the alkali region of Western United States. Potassium nitrate contains a large percentage of oxygen which is readily given up and is well adapted for pyrotechnic compounds. It gives a beautiful violet flame color in burning. Another use is in smoke-tracer compounds with sulphur and arsenic, and in flares and smoke torches. Its function is to furnish oxygen in concentrated form. See also Niter cake, and Sodium nitrate.

**Potters' flint.** A finely ground flint used for mixing with porcelain to reduce the firing and drying shrinkage, and to give body rigidity to prevent deformation. It is also used in enamel mixtures. The requirements are that it be a good white, all pass a 140-mesh sieve, and contain no iron oxide. All true potters' flint is ground from pebbles imported from France. The pebbles are gathered on the sea beaches and are derived from the weathering of the chalk cliffs. They contain 99 per cent of silica. See Silica flour.

**Pozzuolana cement.** Also sometimes referred to as Puzzolana cement. A volcanic material found near Pozzuoli, Italy, and in several other places in Europe, and employed as a building cement. It is a volcanic lava modified by steam or gases so that it is powdery and has acquired hydraulic properties. The chief components are silica and alumina, and the color varies greatly, being white, yellow, brown, or black. The crude material is screened and ground. It has been employed as a construction cement since ancient times. Trass is a similar material found in the Rhine district of Germany. Santorin is a light-gray volcanic ash with somewhat similar characteristics from the Greek

Island of Santorin. A variety of Pozzuolana is made from granulated slag and sometimes referred to as Slag cement.

**Precious metals.** A general term for the expensive metals that are used for coinage, jewelry, and ornaments. The name is limited to gold, silver, and platinum, expense or rarity alone not being the determining factor, but rather the setting of a value by law, with the coin having an intrinsic metal value. The term Noble metal is not synonymous, although a metal may be both precious and noble, as platinum. Noble metals are those metals which are highly resistant to acids and to corrosion by themselves unalloyed. The Noble metals are gold, platinum, iridium, rhodium, osmium, and ruthenium. Radium and certain other metals are more expensive than platinum but are not classed as precious metals. See Rare metals. Because of the expense of the platinum noble metals, they may be alloyed with gold for use in chemical crucibles. Platino is an alloy of 89 per cent gold and 11 platinum. Palau is the name of an alloy of gold and palladium, and Rhotanium is a Rhodium-gold alloy.

**Pre-finished metals.** Sheet metals which have a polished surface of another metal plated on one side. They are used for stamped parts to save plating and polishing of the articles after manufacture. They are usually sheet copper, zinc, or brass, with nickel or chromium polished surfaces. They are also marketed in stripes or patterns for making electrical appliance parts, and the polished corrosion-resistant metal may be bonded to the base metal. Brassoid, of the American Nickeloid Company is brass bonded to zinc; Chromoloid is chromium bonded to zinc; and Nickeloid is a sheet zinc with a polished nickel surface.

**Primer.** A surfacing material employed in painting or finishing to provide an anchorage or adhesion of the finishing material. A primer may be colorless or it may be with color. In the latter case it is sometimes called an Undercoat. A primer is distinct from the filler coat used on woods to fill the pores and thus economize on the more expensive finish. Primer coats of red lead paint are used on construction steel to give corrosion resistance. A primer is especially required in the finishing of sheet-

metal objects that are likely to receive dents or severe service, but they are not always necessary for castings or roughened surfaces. For sheet-metal work, baked enamels were formerly much used for the primers for the lacquer finishes, but pyroxylin and resinoid primers give good adhesion and are less expensive.

**Proplatinum.** The trade name of a white alloy used as a substitute for platinum. A typical analysis shows a content of 72 per cent nickel, 23.6 per cent of silver, 3.7 per cent of bismuth, and 0.7 per cent of gold. The platinum substitute known as Platine-autitre contains 65 to 83 per cent of silver and the balance platinum. Argent français, or French silver, is a copper-nickel alloy with from 20 to 40 per cent of silver and sometimes zinc.

**Protein plastics.** Organic plastic molding materials produced by the isolation or precipitation of proteins from animal or vegetable products and hardening or condensing into stable compounds which can be molded into sheets or fiber. The oldest of these products is casein. See Casein plastics. Proteins employed are the blood albumins, or the proteins from soybeans or other vegetable materials. They are usually condensed with aldehyde or with various mineral salts or acids. Nylon, of the E. I. du Pont de Nemours & Company, is a synthetic protein plastic of this type which is made into fine filaments for use in making textiles of various kinds. The fiber is similar to natural silk in appearance, with great strength, elasticity, and toughness. Exton is this material in harder and coarser fibers used for brushes. It is more durable than natural bristles.

**Proustite.** An ore of the metal silver, occurring in silver veins associated with other metals. It is found in the mines of Peru, Mexico, Chile, and in Nevada and Colorado. It is also called light Ruby silver and is a sulpharsenite of silver of the composition $Ag_3AsS_3$, containing theoretically 65.4 per cent of silver. It commonly occurs massive, compact, in disseminated grains. The hardness is 2 to 2.5, specific gravity 5.55, and the color is ruby-red with an adamantine luster. See Pyrargyrite.

**Pulpstones.** Large blocks of sandstone cut into wheels and used for grinding, chiefly for the grinding of wood pulp in paper

manufacture. The American pulpstones are produced in Ohio and West Virginia. The sandstones required for pulpstones must be uniform in texture, have sharp grains, medium hardness, and be composed of even quartz grains of which 85 per cent will be retained on a 150-mesh screen, and 90 per cent on a 200-mesh screen. The cementing material may be siliceous, calcareous, or argillaceous, but must be firm enough to hold the stone together when working under pressure, and soft enough to wear faster than the quartz grains and prevent glazing. The standard diameter of pulpstones is 54 in. and width of face 27 in. The stones are aged or seasoned from 1 to 2 yr. before use. Aging is sometimes quickened by heating the stones to about 180°F. in a closed room and cooling slowly. See also Grindstones, and Sandstone.

**Pumice.** A porous, frothlike volcanic glass which did not crystallize due to rapid cooling, and frothed with the sudden release of dissolved gases. Powdered or ground pumice is used as an abrasive for fine polishing, in metal polishes, in scouring compounds and soaps, and in plaster and light-weight concrete and pozzuolanic cement. In very fine powder it is called Pounce when used for preparing parchment and tracing cloth. Pouncing paper is paper coated with pumice used for "pouncing" or polishing felt hats. Pumice is grayish white in color, and the fine powder will float on the surface of water. The natural lump pumice contains 65 to 75 per cent of silica, 12 to 15 alumina, and 4 to 5 each of soda and potash. It is produced chiefly in California and New Mexico. Pumicite is a volcanic dust similar in composition to pumice, found in large beds in the Western United States. Seismotite is a trade name for pumicite used as an abrasive in scouring compounds. Slag pumice, or Artificial pumice, is made in Germany by treating molten slag with less water than is required for granulation. It is used as an aggregate in light-weight concrete and as a heat insulator. Obsidian, or Volcanic glass, will change into pumice when melted. Obsidian was used by the ancients for instruments and by the American Indians for arrowheads and knives. Hawaiian obsidian, or Tachylite, also known as Basalt glass, is a volcanic glass from Oahu, Hawaii. It

is jet black, takes a fine polish, and is used for making ornamental articles.

**Purpleheart.** The wood of several species of trees of the genus *Copaifera*, of the order *Leguminosae*, native to tropical America. The color of the wood is brown, the heartwood turning purple on exposure. The grain is open and fine. The wood weighs about 53 lb. per cu. ft., is very hard, strong, and durable. It is used for machine and implement parts, and turnery.

**Purple of cassius.** Also called Gold-tin purple. A brown powder used for coloring enamels and for making Ruby glass. It is a mixture of the yellow gold chloride, $AuCl_3$, and the dark brown tin oxide, $SnO$, produced by the reaction of solutions of gold chloride and tin chloride.

**Putty.** A mixture of calcium carbonate with about 18 per cent of linseed oil, with sometimes white lead added. It is used for cementing window glass in place and also as a filler for patterns. Litharge is often added to putty for steel sash. Another putty for steel contains red lead, calcium carbonate, and linseed oil. The dry pigment for putty, Whiting putty, according to A.S.T.M. specifications contains 95 per cent of calcium carbonate and 5 per cent of tinting pigment. White lead putty contains 10 per cent or more of white lead mixed with the calcium carbonate. Putty powder is a mixture of lead and tin oxides, or a mixture of tin oxide and oxalic acid, or it may be merely an impure form of tin oxide. It is used in enameling and for polishing stone and glass, and as a mild abrasive for dental polishes. Caulking putty, used for setting window and door frames, is made of asbestos fibers, pigments, and drying oils, or sometimes with rubber or resins.

**Pyrargyrite.** An ore of silver, known also as dark ruby silver. It is a sulph-antimonite of silver, $Ag_3SbS_3$, containing 22.3 per cent of antimony and 59.8 per cent of silver. It is found in various parts of Europe, in Mexico, and in Colorado, Nevada, and New Mexico. It occurs in crystals or massive and also in grains. Its hardness is 2.5 and specific gravity 5.85. The color is dark red to black, showing ruby-red in thin splinters.

**Pyrolusite.** The most important manganese ore. It is mined in various parts of Europe, Australia, Japan, Brazil, Argentina, Canada, and the United States. It is a manganese dioxide, $MnO_2$. It has an iron-black color, a metallic luster, and a radiating columnar structure. Its specific gravity is 4.75 and hardness 2 to 2.5. Besides its use as a source of the metal manganese, pyrolusite is used as a drier in paints, a decolorizer in glass, and in electric batteries. When used as a decolorizer for glass, it is often called Glassmakers' soap. Bog manganese, known as Wad, is an impure hydrous mixture of oxides of manganese, $MnO_2$ and MnO, together with oxides of cobalt, copper and iron, and with silica and alumina. It is a soft friable mineral of black or brown color, and usually contains 10 to 20 per cent of water. It is used in the manufacture of chlorine, and also as a flux. High-grade manganese ore for the production of ferromanganese should contain above 35 per cent of manganese.

**Pyrope.** One of the six varieties of garnet, used as an abrasive coating for paper and cloth. The color is deep red to nearly black, and the hardness is 6.5 to 7.5. The composition of pyrope is $Mg_3Al_2(SiO_4)_3$. The crystals are sometimes transparent and are then used as gem stones. Rhodolite, a pale rose or purple garnet used as an abrasive, is a mixture of two parts of pyrope and one of almandite. It has the same hardness as pyrope and is found in various parts of the Eastern United States.

**Pyrophoric alloy.** A sparking metal used for gas and cigarette lighters. The first patent for a pyrophoric alloy was obtained in 1903 by Auer von Welsbach. See Auer metal. A French pyrophoric alloy contains 10 per cent of manganese and antimony, up to 20 per cent of chromium, and up to 15 per cent of titanium. A pyrophoric metal can also be made by the reduction of basic bismuth nitrate. Misch metal and Auer metal are the common pyrophoric alloys.

**Pyrophyllite.** An aluminum silicate mineral found in North Carolina, used as a substitute for talc. It is similar to talc in structure and appearance, but its composition, $Al_2Si_4O_{10}(OH)_2$, is more nearly like kaolin. It is white, gray, or brown, with a

pearly or greasy luster, specific gravity of 2.8, and hardness 1 to 2. Compact varieties of the mineral are made into slate pencils and crayons. A fine-grained compact rock mined in South Africa, composed of about 90 per cent pyrophyllite, with rutile and other minerals, is called Wonderstone, and is used for table tops and switchboard panels. It cuts easily and is resistant to weathering, acids, and heat. Pyrax, of the R. T. Vanderbilt Company, is pyrophyllite in fine white powder of 100 mesh, with specific gravity of 2.6, used as a filler in rubber. See Talc.

**Pyroxylin.** A trade name for cellulose nitrate in a solvent, used for making celluloid, adhesives, rayon, lacquers, and artificial leather. The solvents may be ethyl acetate, ether, amyl acetate, or fusel oil. Pyroxylin is colorless to amber colored. It burns readily but is not dangerously explosive. See Nitrocellulose. It dries on evaporation of the solvent into a tough, flexible, and resistant film which has good adhesion to almost any type of surface. It thus forms a valuable base for lacquers and adhesives. Pyroxylin lacquers contain inert pigments, sometimes vegetable oils to lengthen the drying time, and sometimes resins or plasticisers to give special properties. They are sold under many trade names, such as Duco, Zapon, and Arcozon. They are quick drying because of the volatile nature of the solvents. They will withstand oils, greases, and alkalies, but are dissolved by alcohol. Pyroxylin plastics, or Cellulose nitrate plastics, consist of pyroxylin hardened with camphor or other material, and employed for molding. They are thermoplastic, are softer than the synthetic molding materials, and are usually employed for ornamental articles. They can be colored with pigments and may contain fillers. The pyroxylin plastics are marketed in sheets, rods, and tubes. They machine easily and can be molded under heat and pressure. They are marketed under many trade names such as Pyralin and Viscoloid, of the E. I. du Pont de Nemours & Company, Inc.; Nixonoid, of the Nixon Nitration Works; Amarith, of the Celluloid Corporation; Fiberloid, of the Fiberloid Corporation.

**Quartz.** The most common variety of silica, $SiO_2$. It occurs mostly in grains or in masses of a white or gray color, but often

colored by impurities. Pure crystalline quartz is colorless and is called Rock crystal. Quartz usually crystallizes in hexagonal prisms or hexagonal pyramids. The grains in sand are often less than 0.04 in., but crystals up to 20 in. have been found. The specific gravity is 2.65. Quartz will transmit the short waves of ultraviolet light; fused quartz or Quartz glass is used for bulbs for photoelectric cells and for optical glass. Quartz crystals have the property of generating an electrical force when placed under pressure and, conversely, of changing dimensions when an electric charge is applied. The best crystals are hexagonal prisms free from twinning, with no bubbles, cracks, or flaws. Brazilian quartz crystals are cut into plates of different sizes to initiate and receive various wave lengths on multiple-message telephone wires, and to obtain selectivity in radio apparatus. Due to its peculiar refractive powers quartz crystal is also employed for the plates in polarization instruments and in lenses. Quartz is harder than most minerals, being 7 on the Moh scale, and is used as an abrasive. When quartz is fused, it loses its crystalline structure and becomes a silica glass with a specific gravity of 2.2, compressive strength of 7,000 lb. per sq. in., and hardness of 5. See Optical glass. Pure fused quartz is employed for crucibles and for tubes and rods for furnaces, as it will withstand rapid changes of temperature without breaking. Virtreosil, of the Thermal Syndicate, Ltd., is Fused quartz, containing 99.8 per cent silica. It comes opaque, translucent, and transparent. It transmits ultraviolet and short wave lengths, has high electric resistance, and a coefficient of expansion about 1/17 that of ordinary glass.

Amethyst, Topaz, and some other gem stones are quartz. The Rose quartz of South Dakota is cut for gems. Jasper is a variety of quartz colored red with iron oxide. It is cut and polished as an ornamental building stone. Egyptian jasper is brown in color with dark zones. Most of the quartz used for abrasives and fillers is crushed and finely ground. Powdered quartz is also used as a flux in melting metals.

**Quartzite.** A rock composed of quartz grains cemented together by silica. It is firm and compact and breaks with uneven, splintery fractures. Most of the quartzites used are made

up of angular grains of quartz and are light in color. Quartzite was derived from sandstones by intense metamorphism. Quartzite is employed for making silica bricks, abrasives, siliceous linings for tube mills, as a structural stone, and as broken stone for roads. It is found as a widely distributed common rock. Medina quartzite, from Pennsylvania, contains 97.8 per cent of silica. The melting point is about 1700°C.

**Quebracho.** The common name for the wood of the Quebracho colorado, or red quebracho tree, *Aspidospera quebracho*, found only along the west bank of the Parana and Paraguay rivers in Argentina and Paraguay. It contains about 24 per cent of tannin, and is valued chiefly as a source of Quebracho extract. The wood is exceedingly hard and has a brownish-red color often spotted and stained almost black. Quebracho is valued as a firewood in Argentina, and is also used for crossties and posts, but it is too brittle for structural work. It takes a fine polish and is very durable, carvings of this wood being in perfect condition after 300 years. The weight is 78 lb. per cu. ft. Quebracho extract is the hard, resinous substance extracted from the wood by boiling. It is brownish black in color and extremely bitter, and the solid extract contains 62 per cent of soluble tannins. The commercial liquid extract contains 25 and 35 per cent tannin. It is employed in tanning leather and is rapid acting, but is seldom used alone as it makes a dark leather. It is mixed with alum and salt, or with chestnut extract.

**Quenching oils.** Oils employed for the quenching of steels in heat-treating. They remove the heat from the steel, but act more uniformly and not as suddenly as water. The oils used in quenching baths are usually compounded, although fish oils alone are sometimes employed. Fish oils, however, have offensive odors when heated. Vegetable oils alone are likely to oxidize and become gummy. Animal oils become rancid. Lard and palm oils give low cooling rates, while cottonseed, neatsfoot, and fish oils give more rapid cooling. Mineral oils compounded with fish, vegetable, or animal oils are sold under trade names and vary considerably in their content. Oil quenching baths are usually kept at a temperature of not over 150°F., by providing cooling

pipes. Tempering oils differ from quenching oils only in that they are compounded to withstand temperatures up to about 525°F.

**Radioactive metals.** Metallic elements which emit radiations that are capable of penetrating matter opaque to ordinary light. They give out light and appear luminous, also having an effect on the photographic plate. The metal radium is the most radioactive of all the elements, and practically its only commercial substitute is mesothorium. It is employed for luminous paints for dials and pointers of instruments and for the hands of watches. Other radioactive elements are uranium, thorium, ionium, actinium, and polonium. These bodies all have high atomic weight. The radiating power is atomic and is unaffected in combinations. Radium and other radioactive metals are changing substances. Radium gives out three types of rays; some of the other elements give out only one or two. The emanations are positively charged and are projected at high velocity. These rays can be deflected by magnetic fields. An aluminum screen completely absorbs the $\alpha$ rays, while lead stops the $\beta$ rays. After breaking up, the rays apparently go into the group of inert gases like argon and helium. By comparison of changing atomic weights, it has been deduced that the metal lead is the ultimate product, and uranium the parent metal, but heavier metals have been produced synthetically. See Transuranic metals. Radium has apparently a period of transfer of several thousand years, while mesothorium disintegrates in little over 5 years. Polonium decays in a short time, losing half its weight in 140 days. See also Radium, Mesothorium, Uranium.

**Radium.** A peculiar radioactive element, symbol Ra, scattered in minute quantities throughout almost all classes of rocks. It was discovered in 1898 by Curie, and the first radium chloride separated from pitchblende in 1902. Radium is only commercially obtainable from the uranium ores, monazite sand, carnotite, and uraninite, and is believed to be formed from the disintegration of uranium or ionium. In the Sudetenland section of Germany it is obtained from the residue of pitchblende after the extraction of thorium oxide, but most of the present supply

comes from carnotite of the Belgian Congo. The ratio of radium to uranium in any uranium ore is always about 1:3,000,000. Radium is marketed in the form of bromides or sulphate in tubes and is extremely radioactive in these forms. In a given interval of time a definite proportion of the atoms break up with the expulsion of $\alpha$, $\beta$, or $\gamma$ rays. The most powerful ray is the $\gamma$, and it is estimated that it has a million times the wave frequency of light. Radium is most widely known for its use in therapeutic medicine, but more than 90 per cent of the production is employed in luminous paints for hands and pointers of watches and instruments, and for luminous signs. It is also used for making inspections of metal castings in place of X-rays. See also Carnotite, Mesothorium, and Uraninite.

**Rafaelite.** Oxidized crude petroleum from seepings. It occurs in large beds on the eastern slopes of the Andes Mountains in Argentina, and is similar in appearance to asphalt. It takes its name from the town of San Rafael, Argentina, near which place large deposits appear. It has the same uses as asphalt and is also capable of being distilled for oils and coal-tar products.

**Ramie.** A fiber used for cordage and for various kinds of coarse fabrics, obtained from the plant *Boehmeria nivea* of temperate climates, and *B. tenacissima*, of tropical climates. The former plant has leaves white on the underside, and the latter has leaves all green. The name Rhea is used in India to designate both forms. The best ramie comes from China. The plants grow in tall slender stalks like hemp and belong to the nettle family. The bast fibers underneath the bark are used, but are more difficult to separate than hemp fiber due to the insolubility of the adhesive gums. The fibers are strong, are fine and white, and are as silky as jute. They are not very flexible and are not in general suitable for ease of weaving, as they act like hairs and have no natural affinity to cling together. The composition is almost pure cellulose, and the material is used for a grade of Cigarette paper. China grass is the hand-cleaned but not degummed fiber. It is stiff and greenish yellow in color. Grass cloth is a woven fabric made in China from ramie. Swatow grass cloth, imported into the United States, is made of ramie fibers in parallel strands not

twisted into yarns. Ramie yarns are knitted into gas mantles, and also used as warp yarns in some woolen goods.

**Rape oil.** An edible, lubricating, and illuminating oil obtained from the seeds of several varieties of the turnip, *Brassica campestris*. It is widely used for mixing with lubricating and cutting oils and for quenching oils. The seeds are very small, an ounce including as many as 40,000 seeds. The seeds contain 40 per cent of oil. The edible oil is cold-pressed and refined with caustic soda. The burning and lubricating oils are refined with sulphuric acid. The iodine value is about 100, the specific gravity is about 0.915, and the flash point 455°F. The oil contains palmitic, oleic, linoleic, and stearic acids, and a characteristic acid, $C_{22}H_{42}O_2$, called erucic acid. Rape oil is frequently blown for use as a lubricant. See Blown oil. Colza oil is a rape oil extracted from French seed, used to mix with mineral oils to make cutting oils.

**Rare metals.** A term given by the U.S. Bureau of Mines to certain metallic elements which are rare in the sense that they are extremely difficult to extract from their ores and are rare commercially. These include the four elements Illinium, Masurium, Alabamine, and Virginium. The last is called Madavium in France. With the rare metals may also be grouped the ultra-heavy metallic elements that are produced synthetically by bombarding heavy atoms with neutrons which stick to them and make them heavier. They are called Transuranic metals, because they find a place in the periodic table beyond uranium or are heavier than uranium. All of these metals are radioactive. Radium is also classed as a rare metal.

**Ratany.** The root of the shrub *Krameria triandria*, which grows in the mountains of Peru, and is used for tanning leather. The commercial root comes in diameters up to 1 in. and in pieces up to 3 ft. in length, and contains about 40 per cent of tannin. Hot water dissolves out the tannin for use in solution. It gives a deep brown color and is usually mixed with other tannins.

**Rattan.** The long slender stem of the palm *Calamus Rotang* and other species, of Ceylon, Burma, and India. It is tough,

flexible, strong and durable, and is used for canes, umbrella handles, and furniture. When split it is used for car seats, baskets, baby carriage bodies, furniture, whips, and heavy cordage. Commercial rattans are in pieces 5 to 20 ft. long. Saran is the name of a flexible woven fabric used for car seat coverings to replace rattan. It is a product of the Firestone Rubber & Latex Products Company, and is a Vinylidene chloride plastic extruded into strands and woven into a box-weave fabric similar in appearance to rattan fabric, but is resilient like rubber.

**Raw bone.** A product resulting from the grinding of animal bones, usually the waste from bone processing. It is used for packing steel for heat-treatment. Dissolved bone, marketed for fertilizer, is the ground bone treated with sulphuric acid. Bone meal, for fertilizer, is produced in packing houses by grinding the cooked bones. It contains about 5 per cent of ammonia and 20 to 25 per cent of phosphoric acid.

**Rayon.** A general trade name for artificial silk. It consists of cellulose in solution squirted through fine holes into chemicals which cause the cellulose to precipitate in the form of fine threads. Various processes differ in the solvents and chemicals used. The chief source of the cellulose is waste cotton or cotton linters, as cotton is almost pure cellulose. Wood may be used after dissolving out the lignin. When the cellulose is reacted in nitric acid, nitrocellulose is formed. This is the best known of the raw products for rayon making. A lesser nitration is used than when making nitrocellulose for explosives. See Nitrocellulose. When acetic acid is used, the product is called cellulose acetate. These substances are dissolved in ether, ethyl or other alcohols, amyl acetate, or other organic solvents. Rayon was first known in 1855. Rayons manufactured by the different processes vary both chemically and physically, but none of them have the physical or chemical properties of real silk. It is, however, widely employed in the same uses as silk, and for many purposes is superior. Rayon is insoluble in caustic solutions and silk is destroyed by such solutions. Cuproammonium silks are not as resistant as the pyroxylin Artificial silks or rayons, but they are stronger. Rayon is dyed in many

colors. Fiber silk is a name sometimes applied in the retail trade to rayon. The Federal Trade Commission has ruled against the use of the term Art silk as being deceptive. Glos, a name originally adopted for this product, has now been abandoned. Chardonnet silk was the French name for rayon. Celanese is a proprietary name for cellulose acetate rayon.

**Red brass.** The standard red brass of the mills has a composition of 85 per cent copper and 15 zinc. See Rich low brass. It has a tensile strength from 42,000 to 75,000 lb. per sq. in., with elongation from 4 to 45 per cent depending upon the degree of hard rolling. The melting point is 1875°F. and weight 0.315 lb. per cu. in. It is resistant to corrosion but does not machine as readily as the brasses with more zinc. Various casting alloys are called red brass, especially the high-copper composition metals used for valves and fittings.

**Red casting brass.** The name of a high-copper brass with good casting properties. It also cuts and finishes well. Its composition as designated by one automobile company is 85 per cent copper, 5 per cent tin, 5 per cent lead, and 5 per cent zinc. It has an average strength of 27,000 lb. per sq. in. and elongation of 18 per cent in 2 in. This is A.S.T.M. brass ingot No. 2. High-grade red casting brass for general service is made from A.S.T.M. brass ingot metal No. 1 containing 85 per cent copper, 1.5 lead, 6.5 tin, and 4 zinc, having a tensile strength of 36,000 lb. per sq. in., elongation of 25 per cent, Brinell hardness of 50 to 60. In the high-copper red casting brass series, for any given content of copper and zinc, the higher the ratio of tin to lead the stronger but less ductile the alloy, and the higher the content of zinc the more ductile the alloy. For cast pipe fittings the American Brass Company uses 80 to 86 per cent copper, 4 to 15 zinc, 2 to 6 lead, and 3 to 6 tin. See Leaded high brass, Valve copper, and Ounce metal.

**Red lead.** A common lead pigment, also erroneously called minium. See Cinnabar. It is a lead tetroxide, $Pb_3O_4$, forming a bright-red or orange-red powder of specific gravity 9.096, insoluble in water. As a pigment it has great covering power

and brilliancy, but red lead which has not been completely oxidized and contains litharge must be applied immediately after mixing to avoid combination with the oil. It is used as a heavy protective paint for iron and steel. Red lead is also used in storage-battery plates and in lead glass. With linseed oil it is used as a lute in pipe fitting. Orange mineral is a pure form of red lead made from white lead and has an orange color. Chemically it is the same as red lead, but it has a different structure, giving to it a more brilliant color. Red lead is made from lead metal by drossing and then heating in a furnace. Fume red lead is a fine grade made from Fume litharge, which is a product made by oxidizing molten lead and passed off as a yellow smoke or fume. Fume red lead is notable for the extreme fineness of its particles, and has an apparent bulk much greater than ordinary red lead. Fume red lead is marketed for pigment as Superfine red lead.

**Redwood.** The wood of the trees, *Sequoia gigantea* and *S. sempervirens*, native to the West Coast of the United States. The wood is light, soft, and spongy. It has a dull red color. The trees are of an immense size, and planks can be obtained 6 ft. in width. The weight of the wood is about 28 lb. per cu. ft. It has a tensile strength of from 7,000 to 11,000 lb. per sq. in. The wood is used in all kinds of common construction. The name redwood is also applied to the dyewood, Brazil wood.

**Refractories.** Substances employed where resistance to very high temperature is required, such as for furnace linings and metal-melting pots. They are composed largely of alumina and silica and are employed in the form of powder to be mixed like cement, or are in the form of bricks. They owe their properties largely to silica, magnesia, and alumina. Clay is the oldest and most common of the refractories. The natural refractories are kaolin, chromite, bauxite, zirconia, magnesite, often marketed under trade names. Refractories may be "acid," such as silica, or "basic," such as magnesite or bauxite, for use in acid or basic process steel furnaces. Graphite and chromite are "neutral" refractories. Magnesia fuses at 3929°F., chromite at 3722°F., and alumina at 3670°F. The fusing point of the

refractory, however, is usually dependent on the binder, as all binders or impurities lower the melting point. The Arco refractory brick of the General Refractories Company, with 60 to 80 per cent alumina, will withstand temperatures from 3290 to 3335°F.

The chief artificial refractories are silicon carbide and aluminum oxide. A refractory cement, marketed by the Carborundum Company under the name of Carbofrax, is silicon carbide with a small amount of binder. Grade No. 4 vitrifies at 2460°F. and will not fuse under 3300°F. The tensile strength at 2550°F. is 1,750 lb. per sq. in. Refrax, of the same company, is composed of silicon carbide held together by crystallization. It will withstand temperatures up to 2240°C., at which point it decomposes. The crushing strength of the brick is 12,500 lb. per sq. in. This type of material can be made only in simple shapes. Aluminite is the name of an alumina refractory of the Philip Carey Company furnished in blocks to withstand temperatures up to 2000°F. Good refractories should be of such a chemical composition that they do not fail below the melting point by great expansion or contraction, or by spalling, that is, by cracking from unequal expansion. A high-grade refractory for melting furnaces should withstand temperatures up to 3300°F. and have high resistance to slag and chemical influences. Fire sand is a sand composed of 98 per cent silica and is very refractory. The natural silica refractories used to replace fireclay for high temperatures should contain at least 97 per cent of silica and not yield too fine a powder on crushing. In order of merit the materials used are chalcedony, old quartzites, and vein quartz. Pinite, from Nevada, is a secondary mineral derived from the alteration of feldspar and other rocks, and is used for kiln linings in cement plants. It will bond alone like clay and has low shrinkage. At 1125°C., the mineral inverts to mullite. Agalmatolite is a massive pinite and can be used in the same way. See Agalmatolite. Bull-dog is an old name for a refractory which is a mixture of ferric oxide and silica made by roasting tap cinder with free access of air. Tap cinder is a basic silicate of iron, $2FeO \cdot SiO_2$, which on roasting takes up oxygen. See also Firebrick, Olivine, Magnesite.

**Refractory cement.** A large proportion of the commercial refractory cements used for furnace and oven linings and for fillers are fireclay-silica-ganister mixtures with a refractory range of 2600 to 2800°F. Cheaper varieties may be mixtures of fireclay and crushed brick, fireclay and sodium silicate, or fireclay and silica sand. An important class of refractory cements is made of silicon-carbide grains or silicon-carbide firesand with clay bonds or synthetic mineral bonds. The temperature range of these cements is 2700 to 3400°F. Silicon-carbide cements are acid resistant and have high thermal and electrical conductivity. For crucible furnaces the silicon-carbide cements are widely used except for molten iron. Alumina and alumina-silica cements are very refractory and have high thermal conductivity. Calcined kaolin, diaspore clay, mullite, sillimanite, and combinations of these, make cements that are neutral to most slags and to metal attacks. They are electrical insulators. Chrome-ore cements are difficult to bond, and soften after continued use.

**Refrigerants.** Gases, or very low-boiling-point liquids used for the heat-absorbent cycle in refrigerating machines. The ideal refrigerant, besides having a low boiling point, should be noncorrosive, noninflammable, and nontoxic. Ammonia is the most common refrigerant. See Ammonia. Many other chemicals are employed. See Ethyl chloride, Carbon dioxide, Sulphur dioxide. Refrigerants are also marketed under trade names. Freon, of the Kinetic Chemical Company, is a colorless, odorless, noninflammable gas of the composition $CF_2Cl_2$, known as Dichloro-difluoro-methane. It liquefies at −21.7°F.

**Resin.** An important group of substances obtained as gums from trees, or manufactured synthetically, as the phenol resins. The common resin of the pine tree is called Rosin. See Rosin. The natural resins are soluble in most organic solvents and are used in varnishes, adhesives, and various compounds. Oleo-resins are natural resins containing essential oils of the plant. The synthetic resins are used chiefly for molding mechanical and electrical parts. Some of the commercial resins are rosin, dammar, mastic, sandarac, frankincense, lac, and anime.

Gum resins, not so soluble in alcohol, are gamboge, myrrh, rubber, gutta-percha, and olibanum. Fossil resins are considered especially valuable, and owe their quality to the long formation. These are amber, kauri, and copal. See also Synthetic resins.

**Resistance wire.** The standard alloy for electrical resistance wire for heaters and electrical appliances is nickel-chromium, but nickel-manganese is also used, and for high-temperature furnaces molybdenum wire is used. The alloy with 80 per cent of nickel and 20 chromium resists scaling and oxidation up to 2100°F. The alloy containing 60 per cent of nickel, 15 chromium, and 25 iron is resistant up to 1830°F., and the alloy with 30 nickel, 20 chromium, and 50 iron, is resistant to 1560°F. Resistance wire of these alloys is made to close tolerances. Molybdenum wire is used for temperatures up to 2900°F. For low temperatures, copper-nickel or nickel-iron alloys are used. A resistance alloy developed by the National Bureau of Standards, called Therlo, contains 85 per cent of copper, 9.5 manganese, and 5.5 aluminum. A Silicon-manganese-nickel alloy is marketed by the Wilbur B. Driver Company under the name of Sparkaloy, and is used for spark-plug wire. Manganin, of this company, contains 70 to 85 per cent of copper, 2 to 5 nickel, and 12 to 15 manganese. It has a tensile strength of 70,000 lb. per sq. in. and a resistance of 290 ohms per cir. mil ft. It is used for coils and shunt wires in electrical instruments. Tophet A, of this company, is a standard 80-20 nickel-chromium alloy. The tensile strength is 120,000 lb. per sq. in. and resistance 650 ohms per cir. mil ft. Tophet C, containing 60 per cent nickel, 16 chromium, and 24 iron, has a resistivity of 675 ohms and is used for temperatures up to 1920°F. Calorite, of the General Electric Company, contains 65 per cent of nickel, 8 manganese, 12 chromium, and 15 iron. Excello metal, of H. Boker & Company, Inc., contains 85 per cent nickel, 14 chromium, and 0.5 each of manganese and iron. It is used in electric heaters for temperatures up to 2000°F. Alumel, of the Hoskins Manufacturing Company, intended for temperatures up to 1250°C., has 94 per cent of nickel, 2.5 manganese, 0.5 iron,

and small amounts of other elements. Calido, of the Driver-Harris Company, contains 59 per cent of nickel, 16 chromium, and 25 iron. Nichrome V, of this company, is the 80-20 alloy. Nichrome S contains 25 per cent of nickel, 17 chromium, and 2.5 silicon. It is marketed in sheet form for temperatures up to 1800°F. Comet metal, of the same company, used for rheostats, contains 30 per cent nickel, 5 chromium, and the balance iron. It has high strength, up to 160,000 lb. per sq. in., and a resistivity of 570 ohms. Hytemco, of this company, is an iron-nickel alloy used for low-temperature wire. The resistance is 120 ohms per cir. mil ft. Magno is a 95 per cent nickel, 5 manganese alloy of this company; Climax metal has 74 per cent iron, 25 nickel, and 1 manganese.

**Rextox.** A rectifying material composed of copper upon which a layer of cuprous oxide has been formed at high temperature. Electric current will flow easily from the oxide to the copper, but only with difficulty from the copper to the oxide. The action, therefore, is to split an alternating current, passing only the direct wave. It is used for rectifying alternating current into pulsating direct current. It was developed by the Westinghouse Electric & Manufacturing Company. Tantalum also has this property.

**Rhenium.** An elemental metal, symbol Re, present in many minerals, but in extremely small quantities. The atomic weight is 186.3 and specific gravity 21.4. Rhenium has a silvery-white color, is very hard, and takes a high polish. Its melting point is 3440°C., or higher than that of tungsten. The metal is obtained from molybdenite, this mineral having from 2 to 20 parts per million of rhenium. It is also found in the Ural platinum ores. It is ductile and malleable. It is resistant to many acids but soluble in nitric acid. As a plating metal it gives a hard, bright deposit, somewhat darker than rhodium. Some rhenium is used in radio and power tubes.

**Rhodium.** A rare metal, symbol Rh, found in platinum ores. It is very hard and is one of the most infusible of the metals. The melting point is 3542°F. It is insoluble in most acids but

is attacked by chlorine and sulphur. The specific gravity is 12.44. Rhodium is used to make the nibs of writing pens, resistance windings in high-temperature furnaces, for the points of thermocouples, as a catalyst in the oxidation of ammonia to nitric acid, for laboratory dishes, and for electroplating jewelry and electric appliances. The plated metal has a pinkish-white luster. The metal is malleable at temperatures above 800°C. It forms a solid-solution alloy with platinum that is easily workable and does not tarnish or oxidize at high temperatures. These alloys are used for thermocouples, and sometimes for chemical apparatus. Rhodium is sold by the troy ounce, one cu. in. weighing 6.56 troy oz.

**Rhodochrosite.** An ore of manganese, found in small quantities in Connecticut, New Jersey, Colorado, and in the silver mines of Hungary and Saxony. It is a manganese protocarbonate, $MnCO_3$, with usually some iron replacing part of the manganese. It is usually a massive cleavable structure, sometimes granular. Its hardness is 3.5 to 4.5 and specific gravity 3.45 to 3.6. The color is rose-red to dark brown, with a vitreous luster.

**Rich low brass.** An alloy of 85 per cent copper and 15 per cent zinc, which is one of the standard mixtures of the brass mills. It is very ductile and has a fine reddish color. It is one of the most malleable of the brasses, and the working stresses can be relieved without softening the metal by heating for a half hour at 275°C. It is essentially a drawing and stamping metal and, unless it contains a little lead, will not machine well. The Guinea gold, used for traders' jewelry, was this metal, or an alloy with 12 per cent of zinc. Pinchbeck metal, originally made by C. Pinchbeck, an English jeweler, contained 88 per cent of copper and 12 zinc. Manila gold, or Traders' gold, contained some lead. Mannheim gold, also for cheap jewelry, contained 83 per cent copper, 10 zinc, and 7 tin. Ormulu gold is another name for high-copper brass. The original Tombac metal of China contained about 15 per cent of zinc. Tournay metal, also for buttons and jewelry, was a French alloy of this composition. Rich gold metal is a brass with 10 per cent of zinc.

This alloy, under the name of Copper-rich brass, is used for decorative purposes, such as for store fronts. The gold color is enhanced by pickling in nitric acid. Argental is a rich low brass whitened and strengthened with about 5 per cent of cobalt. See also Gilding metal, Brass.

**Roman cement.** A Natural cement made by calcining various sandy limestones and grinding the product. The limestones used usually contain 60 to 70 per cent of calcium carbonate, 14 to 20 per cent of silica, and 5 to 10 per cent of alumina. Calcination is done at a moderately red heat, and the porous clinker is crushed and finely ground. Roman cement is cheaper and will set more quickly than portland cement, but is softer and inferior in strength.

**Roofing granules.** Graded particles of crushed rock, slate, slag, glass, porcelain, or tile, used as surfacing on asphalt roofing and shingles. Granules have practically superseded gravel for this purpose. Ceramic granules are produced from clay or shale fired and glazed with metallic salts. They constitute the majority of granules used and are preferred because the color is uniform and they are impervious to moisture. Slate granules are used for surfacing prepared roofing.

**Roscoelite.** One of the most important ores of vanadium produced in the United States. It is a muscovite mica in which part of the aluminum has been replaced by vanadium. It occurs in micalike scales varying in color from green to brown. It has a specific gravity of 2.9. The ore mined in Colorado contains only about 1.5 per cent of vanadic oxide.

**Rosein.** A light-weight, white metal used chiefly for making jewelry and ornamental articles. It contains 40 per cent of nickel, 30 of aluminum, 20 of tin, and 10 of silver. It can be worked easily and takes a good polish. Mock silver is an aluminum alloy containing about 10 per cent of tin and 5 of copper. See also Jewelry alloy.

**Rosewood.** The wood of the Jacaranda tree, *Dalbergia nigra*, used for fine cabinetwork, pianos, novelties, and expensive furniture. It should not be confused with the wood of the tree

*Physocalymma floridum*, which also comes from Brazil and is there called "pao rosa" or rose wood. The color of rosewood is dark brown, and it takes a beautiful polish. It has a characteristic fragrance. It is very hard and has a coarse, even grain. The weight is 54 lb. per cu. ft. Indian rosewood is from the tree *Dalbergia sissoo* of India. It is also called Sissoo, and is a beautiful, brown, hard wood employed for carvings. In Europe it is also used for parquet floors. Borneo rosewood, also known as Ringas, is the wood of several species of trees of the genus *Melanorrhoea* of Borneo. The wood has a deep red color with light and dark streaks. It has a close texture suitable for carving.

**Rosin.** The common resin of several varieties of the pine tree, found widely distributed in North America and Europe. It is obtained by cutting a longitudinal slice in the tree and allowing the exudation to drip into containers. The liquid resin is then distilled to remove the turpentine, and the residue forms the rosin. It is a reddish-brown translucent solid, inflammable, and easily fusible. It consists chiefly of Abietic acid, of the empirical formula $C_{19}H_{29}COOH$, and is one of the cheapest organic acids available. There are two general kinds: Wood rosin, and Gum rosin. The specific gravity is 1.08 and the melting point is 100 to 140°C. Rosin is soluble in alcohol, turpentine, and in alkalies. It is used in varnishes, paint driers, soluble oils, paper sizing, belt dressings, and as a filler for other resins. The rubber industry uses 5,000,000 lb. annually, and gum rosin is also used with rubber in nonvulcanizing cements. Wood rosin is used in linoleum manufacture.

Rosin is generally graded commercially by letters from B to W, according to color. The darkest grade is B, and the lightest is W. Extra grades are A, nearly black, and WW, water white. The dark grades of wood rosin are considered inferior. They have high melting point and low acid number and are used for making rosin oil, for battery wax, thermoplastics, dark varnish, and for linoleum manufacture. The ruby-red wood rosin, obtained by extraction from "fat" pine wood, has high acid number, 155, and low melting point, 175°F. It is used for printing inks, paper size, and adhesives. Rosin is usually mar-

keted in wooden barrels. A barrel of rosin under Georgia law is 280 lb. Hardened rosin is a weak resinate made by adding 6 to 8 per cent of high-calcium lime to melted rosin. It is used in some varnishes. Rosin ester, or Ester gum, is rosin combined with glycerin by a special process, or esterification. It is used with tung oil in enamels and varnishes. Naval stores is a name given to rosin and turpentine. Colophony is a chemical name for rosin before the distillation of rosin oil. It was referred to by early writers as Greek pitch, but the so-called Greek fire, used by the ancients as an incendiary material, was described as tow and pine sawdust impregnated with powdered rosin, pitch, and sulphur. Burgundy pitch is a name for rosin and mineral oil, used for friction tape and for compounding with rubber. It is amber colored, has a specific gravity of 1.04, and a melting point of 212°F. Hydrogenated rosin has greater resistance to oxidation than common rosin, has less odor and taste, and is more stable to light. It is used in protective coatings, paper size, adhesives, and soaps. Staybelite resin is the trade name of the Hercules Powder Company for a hydrogenated rosin. Vinsol resin, of this company, is a hard, high-melting, dark resin produced from the distillation of wood. It is soluble in alcohols, has a melting point of 115°C., and is used for varnishes where light color is not essential, and for compounding in thermoplastics.

**Rosin oil.** An oil produced by the dry distillation of rosin at a temperature of 200 to 360°C. There are two qualities of the oil, a light spirit, Pinolin, which forms from 1 to 5 per cent of the rosin, and a bluish, heavy oil, which forms 80 to 84 per cent. It contains abietic acid and has an acid value of about 28. The commercial oil has a specific gravity of 1.020 with a flash point of 160 to 170°C. The refined oil is a yellow liquid with a pleasant odor and may be used for adulterating turpentine. It is also employed as a plasticiser in rubber, as a tack producer in rubber cements, and in synthetic molding resins. When treated with lime, it may be used to mix with lubricating oils. The light distillate is used sometimes in pharmacy under the name of Oil of amber. Blended rosin oil is a mixture with mineral oils.

**Rottenstone.** A soft friable earthy stone of light gray to olive color, used as an abrasive for metal and wood finishing. It resembles Missouri tripoli, and is derived from the weathering of siliceous-argillaceous limestone, with generally from 80 to 85 per cent of alumina, 4 to 15 per cent of silica, and 5 to 10 per cent of iron oxides. Rottenstone was largely imported from England, but a variety is found in Pennsylvania. It is finely ground and is marketed either as a powder or molded into bricks. The latter form is used with oil on rag-wheel polishing. A 250-mesh powder is used as a filler in molding compounds.

**Rouge.** A hydrated iron oxide used for polishing metals. It has a hardness of 5.5 to 6.5 and is made by calcining ferrous sulphate and driving off the sulphur. The color is varying shades of red; the darker the color, the harder the rouge. The grains are rounded, unlike the grains of crocus. The pale red rouge is used for finishing operations, and the other grades are used for various polishing of metal surfaces. Stick rouge is made of finely crushed powder. Black rouge, also called Glassite, is magnetic oxide of iron made by precipitating ferrous sulphate with caustic soda. It is used for buffing but is not popular because it stains the skin. Green chrome rouge is Chromium oxide, CrO, made by the strong heating of chromic hydroxide. It is used for buffing stainless steels. Satin rouge is a name applied to lampblack when used as a polishing medium, in the form of brick for polishing silverware. The name rouge is also applied to crocus. See Crocus.

**Rubber.** A gum resin exudation of several species of trees of the genus *Hevea*, growing in all tropical countries and now cultivated on plantations in the East Indies. It was formerly referred to as India rubber, and the name given it by Charles Goodyear was Gum elastic. Brazilian rubber is sometimes called Para rubber. Caoutchouc is a name for crude rubber. The milklike juice, or latex, is dried over a fire into a dark, solid mass for shipment, but latex is also shipped. See Latex. Crude rubber is usually marketed as crepe or ribbed smoked sheet in various grades. Rubber has the property of being vulcanized by heating with sulphur, making it harder, and more

elastic in the low-sulphur compounds. The ordinary Soft rubber contains only from 3 to 6 per cent of sulphur, and may also contain factice or other softening medium giving varying degrees of elasticity, flexibility, and resiliency. When 30 per cent of sulphur is added and heated, hard rubber is formed. See Vulcanized rubber. Vapor-cured rubber is rubber vulcanized by sulphur chloride fumes and neutralized with magnesium carbonate. It is used for thin goods only. Acid-cured rubber is rubber cured in a bath of sulphur chloride in a solvent.

For the rubber used in making automobile tires large percentages of carbon black and zinc oxide are used to reinforce it and give added wearing qualities. Rosin and other resins and gums impart softness to rubber compounds. Carbon black gives high wear resistance. Zinc oxide is an accelerator as well as a filler and strengthener. Litharge, lime, and magnesia stiffen rubber and speed up vulcanization. Red rubber is colored with antimony red. Many trade-named accelerators, fillers, and stiffeners are marked for rubber compounding. Cycline oil, of the Monsanto Chemical Company, is a mixture of vegetable and mineral oils for softening molding rubbers. Tackol is a mixture of oils and resins used as a rubber plasticizer. Trimene, of the Naugatuck Chemical Division, U.S. Rubber Company, is an aldehyde amine with stearic acid, used to aid the cure and stiffen rubber. See also Factice. Whiting, clay, and barites are used as fillers, but many of the fillers also give added properties to the rubber. Calcene, of the Columbia Alkali Corporation, and Kalvan, of R. T. Vanderbilt Co., Inc., are trade names for calcium carbonate used to give crack and tear resistance and high stretch to rubber. Silene, of the Columbia Alkali Corporation, is a precipitated Calcium silicate of fine particle size used to add tear resistance to the rubber.

The annual consumption of rubber in the United States exceeds 500,000 tons. About three-quarters is used for automotive tires, but there are innumerable other uses of rubber for molded goods, elastic products, and waterproofings. Many of the products are sold under trade names. Cavalite is silk coated with rubber marketed by E. I. du Pont de Nemours & Company, Inc., for rainwear. Sponge rubber is rubber expanded with a

cellular structure. See also Latex foam. Sponge rubber is used for upholstery, such as Airtex, of the Firestone Company.

Rubber contains Isoprene, $C_5H_8$, which is the building unit of balata, gutta percha, and many other rubber-like materials. The exact formula of rubber is unknown. The so-called Synthetic rubbers are not rubbers, but are rubberlike products. The original Butadiene rubber produced in Germany from butane gas by conversion to butadiene was not as elastic, but had greater wear resistance than natural rubber. It was also resistant to mineral oils, which break down natural rubber.

Neoprene, formerly called Duprene, of E. I. du Pont de Nemours & Company, Inc., is a polymerized chloroprene, $H_2C{:}CCl{\cdot}CH{:}CH_2$, produced from acetylene. It is a rubberlike material but is more resistant to oils and chemicals than rubber. It is also stable to light and aging and more heat resistant than rubber, but the elasticity is less. It is not vulcanized with sulphur but is self-curing by polymerization. It is valued for hose, gaskets, belting, molded goods, coated fabrics, and adhesives. The specific gravity is 1.25, but with fillers it ranges from 1.4 to 1.8. The tensile strength is 200 to 4,000 lb. per sq. in., depending upon the polymer and the fillers. The tensile strength of ordinary true rubber of low vulcanization is 800 to 1,200 lb. per sq. in. of the original cross section.

Thiokol, of the Thiokol Corporation, is an olefin polysulphide reaction product, which can be vulcanized like rubber and is used for molded products, wire covering, and coatings. Koroseal, of the B. F. Goodrich Company, is a polymer of a vinyl halide, and is used for gaskets, fabric impregnation, and cable sheathing. The strength is from 1,000 to 7,000 lb. per sq. in., depending upon the amount of plasticizer. The dielectric strength is 250 to 850 volts per 0.001 in. thickness. In solution this material, known as Korolac, is used for lining acid tanks and covering plating racks. It is resistant to acids.

There are at least six general types of Synthetic rubbers: Chloroprene polymers, such as Neoprene; Butadiene polymers, such as Buna; Organic polysulphides, such as Thiokol; Isobutene polymers, such as Vistanex; Vinyl chloride polymers, such as Koroseal; and Dimethyl butadiene polymers, such as Methyl

rubber. In general, these rubbers are made in two steps, by manufacture of the monomer, and then by polymerization or condensation. Thiokol A is made by the reaction of sodium tetrasulphide and ethylene dichloride. Butyl rubber, of the Standard Oil Company, is a variation of Buna rubber made from petroleum. This rubber manufactured by the B. F. Goodrich Company is called Ameripol. Methyl rubber is made by Bayer & Company. Perduren is a Buna rubber of I. G. Farbenindustrie. Resenit is a Russian polysulphide, and Vulcaplas is a similar English rubber. Korogel is a highly plasticized Koroseal. Mustone is a Japanese chloroprene rubber. Perbunan is a butadiene rubber of the Standard Oil Development Company. Chemigum is a rubber derived from petroleum with patents held by the Goodyear Tire & Rubber Company. It is easier to process and cheaper than Buna rubber. The present Buna rubbers differ from the original German products. Buna S is a copolymer of butadiene and styrene. All of the synthetic rubbers are more resistant than natural rubber, but not as flexible. Tensolite, of the Tensolite Corporation, used to make filaments or fibers for filter cloth, hair nets, and braided goods, is a chlorinated natural rubber. See Chlorinated rubber.

**Rubber powder.** Also called Granulated rubber. A powder prepared usually by spraying latex containing added protective colloids into a current of hot air and drying the particles. The latex is protected or stabilized with an ammonia solution of zinc ammonium sulphate; the final rubber powder contains 8 per cent of zinc ammonium phosphate and 2 per cent of magnesium carbonate. It can also be made by precipitation. Rubber powder is fine, passing through a 200-mesh screen. It is used chiefly in molding and caulking compounds. Vulcanizing and compounding materials are sometimes added to the powder for marketing as molding powders. Hard-rubber dust is made from hard-rubber scrap and is used as a filler in rubber.

**Rubidium.** A rare metallic element, symbol Rb, belonging to the group of alkali metals. The chief occurrence of rubidium is in the mineral lepidolite, although it is found in other minerals, and in tea, coffee, tobacco, and certain other plants. It

is a silvery-white metal, with a specific gravity of 1.52 and a melting point of 39°C. It takes fire easily in the air, and like potassium it decomposes water. It can be obtained by electrolysis but has few industrial applications as yet due to its rarity and instability. Its chief use is for coating photoelectric cells for telephotographic and television instruments. For the photoelectric cell an extremely thin layer of rubidium is applied to the inside of the glass, and it is preferred to caesium.

**Ruby.** A transparent variety of the mineral corundum, having a beautiful red hue. It ranks with the best grades of previous stones as a gem stone, but is also used for pivot bearings in watches and fine instruments. The specific gravity is 4.03 and the hardness is 9, being nearly equal in hardness to the diamond. The color is due to chromic oxide. Most of the best rubies come from Upper Burma. Darker stones come from Siam. The carmine-red, or "pigeon's blood," stones are the most highly prized, and in large sizes are of more value than diamonds. For bearing uses synthetic rubies are largely substituted for the natural stones. See also Corundum. Synthetic ruby, and other Synthetic gems, notably the Aquamarine and Tourmaline, are made on a large scale at Bitterfeld, Germany, for jewelry and for bearings for watches and instruments. They are made from argillaceous earth at high temperatures; the crude product is a pear-shaped crystal 6 mm. in length. They have the same composition and crystal structure as the natural stones.

**Rustless iron.** A name given by some companies to the chromium-iron and chromium-nickel-iron alloys which differ from the stainless and corrosion-resistant type of steels only in that they have very low carbon, usually not over 0.15 per cent. Defirust, of the Rustless Iron Corporation of America, contains 12 to 15 per cent of chromium and 0.10 carbon, with some nickel. The scaling point is at 1250°F. Special Defirust has 15 to 18 per cent of chromium and withstands temperatures up to 1500°F. The type known as Rustless iron has 21 per cent of chromium and is resistant to acid solutions. Defiheat iron, of this company, contains 26 to 29 per cent of chromium and 0.20 carbon, with a small amount of nickel. The tensile strength

is 70,000 to 95,000 lb. per sq. in., Brinell hardness 175 to 210, and scaling point 2100°F. Enduro AA, of the Republic Steel Company, is a chromium-iron containing 16 to 18 per cent of chromium and 0.12 carbon. See Delhi rustless iron, Uniloy, Stainless iron, Heat-resistant alloys, Nickel-chromium alloys.

**Ruthenium.** A rare metallic element, symbol Ru. It is a hard, white metal, having a specific gravity of 12.1 and a melting point of about 4440°F. The Brinell hardness of the annealed metal is 220. It can be obtained in the metallic state by heating Ruthenium oxide, $RuO_2$, obtained from the residue of platinum ores, in hydrogen. It is insoluble in most acids and is not dissolved by aqua regia. Ruthenium is used as a hardener in platinum alloys and has a powerful hardening effect on this metal. It is sold by the troy ounce, a cu. in. weighing 6.38 troy oz.

**Rutile.** The most common ore of the metal titanium. It is a titanium dioxide, $TiO_2$, containing theoretically 60 per cent of titanium. Its usual occurrence is crystalline or compact massive, with a specific gravity of 4.18 to 4.25 and a hardness of 6 to 6.5. The color is red to black. Rutile is found in granite, gneiss, limestone, or dolomite. It is obtained commercially from beach sand of northern Florida, and Espirito Santo, Brazil, and is mined in Virginia. It is marketed in the form of concentrates with 94 to 96 per cent of titanium oxide. Rutile is used extensively in the ceramic and enamel industries as a coloring agent.

**S.A.E. steels.** The common designation for the standard grades of steel approved by the Society of Automotive Engineers. These steels are made regularly by the various mills and are known by their designating numbers. The first number indicates the class of steel, as follows: carbon steel, 1; nickel-carbon, 2; nickel-chromium, 3; molybdenum, 4; chromium, 5; chromium-vanadium, 6; tungsten, 7; and silicon-manganese steel, 9. The second figure indicates the approximate percentage of the predominating alloying element. The last two or three figures indicate the approximate carbon content in hundredths of a

per cent. Thus, S.A.E. 2350 steel is a nickel steel containing 3 per cent of nickel (2.75 to 3.25) and 0.50 per cent of carbon (0.45 to 0.55). The manganese steels, with manganese from 1.60 to 1.90 per cent, are designated by the letter T before the initial 1. Thus, S.A.E. T1350, contains 0.45 to 0.55 carbon and 1.60 to 1.90 manganese. The S.A.E. steels are made to close specifications of manganese, sulphur, and phosphorus content and, since they are very uniform in quality and usually carried in stock, they have been widely adopted for use in all kinds of products. The silicon range for the basic open-hearth alloy steels is 0.15 to 0.30; for electric and acid open-hearth steels it is 0.15 minimum.

**Sal ammoniac.** The common name for Ammonium chloride, $NH_4Cl$, a white crystalline substance employed as a soldering flux and also used in electric batteries, textile printing, and for making other ammonium compounds. The specific gravity is 1.52. When heated, it volatilizes without melting.

**Salmon oil.** A pale yellow oil obtained as a by-product in the salmon-canning industry, and employed as a drying oil for finishes and also used in soaps. There are different classes of the oil, depending upon the type of salmon. The oil contains palmitic and other acids. The specific gravity is 0.926. It has a high iodine value, 168, but it does not form an elastic skin on drying and is therefore inferior for use in most varnishes.

**Salt.** The common name for Sodium chloride, known in mineralogy as Halite. It is widely used industrially for preservative purposes, salt brine quenching baths, freezing mixtures, manufacture of soda ash and various chemicals, and for the extraction of gold by the chlorination process. Salt is a very stable compound of the composition NaCl, containing theoretically 60.6 per cent of chlorine and 39.4 per cent of sodium. It usually contains impurities such as calcium sulphate, and calcium and magnesium chlorides. It occurs in crystalline granular masses with cubical cleavage, known as Rock salt, or Mineral salt, and is plentiful in most parts of the world. It is easily soluble in water and is found in all waters. It is

obtained by evaporation from sea water, which also contains magnesium chloride and other salts. Bay salt is an old name for salt extracted from sea water, now known as Solar salt. Refined California solar salt is 99 per cent pure sodium chloride. From the salt wells of Michigan the bromine, magnesium, and other elements are extracted and the brines form an important source of these products. The hardness of salt is 2.5, the specific gravity 2.1 to 2.6, and melting point 1472°F. It may be white or colorless, and when impure has shades of yellow, red, or blue.

In making brines, 100 parts of water at ordinary temperature will dissolve about 36 parts of salt. Brines used for quenching steel contain from 10 to 15 per cent of salt and have a high cooling rate, but corrode the steel.

In the United States, salt is produced on a commercial scale in 15 states, with an output of more than 7,000,000 tons annually. Commercial salt is marketed in many grades depending chiefly on the size of the grain. The term Industrial salt refers rather to the method of packing and shipping than to a grade distinct from Domestic salt, but most of the industrial salt is rock salt; the bulk of the domestic salt is evaporated salt. Salt obtained by simple evaporation of sea water contains salt-resistant bacteria which are capable of developing in salted hides or fish and injuring the material. Mineral salt is thus preferred for these purposes. Sodium hypochlorite, NaOCl, is a stable, noncorrosive salt used in tanneries. Merclor D is a trade name of the Monsanto Chemical Company for this material in water solution. Sodium chlorite, $NaClO_2$, is a salt used for bleaching paper.

**Sand.** An accumulation of grains of mineral matter derived from the disintegration of rocks. It is distinguished from gravel only by the size of the grains or particles, but is distinct from clays which contain organic materials. Sands that have been sorted out and separated from the organic material by the action of currents of water or by winds across arid lands are generally quite uniform in the size of grains. Usually commercial sand is obtained from river beds, or from sand dunes originally formed by the action of winds. Much of the earth's surface is sandy,

and these sands are usually quartz and other siliceous material. The most useful commercial sands are composed chiefly of silica, often above 98 per cent. Other materials in sand are feldspar, garnet, zircon, and tourmaline. Silica sands for making glass must be free from iron. Sand is used for making mortar and concrete and for polishing and sand-blasting. Sands containing a little clay are used for making molds in foundries. Clear sands are employed for filtering water. Sand is sold by the cubic yard or ton but is always shipped by weight. The weight varies from 2,600 to 3,100 lb. per cu. yd., depending on the composition and size of grain. Standard sand is a silica sand used in making concrete and cement tests. The grains are free of organic matter and will pass through a 20-mesh sieve, but will be retained on a 30-mesh. See Sandpaper, Abrasive sand, Sandblast sand.

**Sandarac.** Known also as White gum, or Australian pine gum. A white, brittle resin obtained as an exudation from various species of the coniferous tree *Callitris*, known as Cyprus pine. The North African sandarac is from the tree *Tetraclinis articulata*, of the Atlas Mountains, and resembles the resin from the Australian tree *Callitris arenosa*. Sandarac is used in varnishes and is soluble in turpentine and alcohol. It melts at 135 to 140°C. It gives a hard, white spirit varnish. Ground sandarac, under the name of Pounce, was formerly used as a pouncing powder and for smoothing parchment and tracing cloth, but is now replaced by other material. See Pumice.

**Sandblast sand.** Any sand employed in a blast of air for cleaning castings, removal of paint, cleaning of metal articles, or for giving a dull rough finish to glass or metal goods, or for renovating the walls of stone or brick buildings. Sandblast sand is not closely graded, and the grades vary with different producers. The U.S. Bureau of Mines gives the following usual range: No. 1 sand should pass through a 20-mesh and be retained on a 48-mesh screen; No. 2 should pass through a 10-mesh and be retained on a 28-mesh screen; No. 3 through a 6-mesh and be retained on a 14-mesh; No. 4 through a 4-mesh and be retained on an 8-mesh screen. No. 1 sand is used for light work where a smooth finish is desired; No. 4 sand is employed

for rough cast-iron and cast-steel work. Sharp grains cut faster, but rounded grains produce smoother surfaces. The sand is usually employed over and over, screening out the dust. In some cases the dust and fine used sand are mixed with clay and blasted wet. This is known as mud blasting and produces a dull finish on steel tools.

**Sandpaper.** A heavy paper coated with sand grains on one side, used as an abrasive, especially for finishing wood. For this purpose ordinary sand has been largely replaced by crushed garnet and artificial aluminum oxide, but the papers are still commonly referred to as sandpaper. The grains of natural sand do not have the sharp cutting edges of grains broken down from larger fragments, and are therefore not as desirable for woodworking as sandpaper made from crushed quartz grains. For this purpose the quartz grains are prepared in grades from the 20 mesh, known as No. 3½, through No. 3, 2½, 2, 1½, 0, 00, and 000. All of the No. 000 grains pass a 150-mesh sieve, with 25 per cent retained on a 200-mesh sieve and 80 per cent on a 325-mesh sieve. Good sandpaper quartz will contain at least 98.9 per cent of silica. The paper used is heavy, tough, and flexible, usually 70- or 80-lb. paper, and the grains are bonded with a strong glue. A patented process is also employed to deposit the grains on end by electrostatic attraction so that the sharp edges of the grains are presented to the work.

**Sandstone.** A consolidated sand rock, consisting of sand grains united with a natural cementing material. The size of the particles and the strength of the cement vary greatly in different natural sandstones. The most common sand in sandstone is quartz, with considerable feldspar, lime, mica, and clayey matter. The cementing material is often fine chalcedony. Silica sandstones are hard and durable but difficult to work. Calcareous sandstone, in which the grains are cemented by calcium carbonate, is called Freestone and is easily worked, but it disintegrates by weathering. Freestone is homogeneous and splits almost equally well in both directions. Chert, formerly used as an abrasive and, when employed in building and paving, known under local names as Hearthstone, Firestone, and

Malmstone, is a siliceous stone of sedimentary origin. It has a radiating structure and splintery fracture and is closely allied to flint. In color it is light gray to black or banded. The colors of sandstones are due to impurities, pure siliceous and calcareous stones being white or cream colored. The yellow to red colors usually come from iron oxides, black from manganese dioxide, and green from glauconite.

Sandstones are employed for grindstones and for building stones. The average compressive strength of sandstone used for building purposes is 12,000 lb. per sq. in., and the average weight is 135 lb. per cu. ft. Sandstones for building purposes are produced under innumerable names, usually referring to the locality. The Blue stone of New York state is noted for its even grain and high crushing strength, up to 19,000 lb. per sq. in. It contains about 70 per cent of silica sand with clay as the binder. Holy-stone is a block of close-grained sandstone, formerly used for rubbing down the decks of ships and still used for rubbing down furniture and concrete work. Briar Hill stone and Macstone are trade names for building blocks consisting of light-weight concrete faced with a slab of sandstone. See also Grindstones, Whetstone.

**Sapphire.** A transparent variety of the mineral corundum. When it has the beautiful blue hue for which it is noted, it ranks with the diamond, ruby, and emerald among precious gem stones. The off-color stones are cut for pointers and wearing points of phonographs and instruments. The specific gravity of sapphire is 4.03, and the hardness is 9. The blue color is from titanic oxide and is rarely uniform throughout the stone. The best gem sapphires come from Ceylon and India, but industrial stones are produced in Montana.

**Sardine oil.** A pale-yellow oil prepared from the refuse obtained in the sardine canning industry on the French and Spanish coasts. Japanese sardine oil is obtained on a larger scale by chopping up the fish and steaming. The oil is used as a drying oil for paints and varnishes and as an adulterant of linseed oil. The specific gravity is 0.927 to 0.933 and iodine value about 185. It contains a high percentage of palmitic acid.

**Satin.** A full-silk, heavy fabric with a close twill, or "satin," weave. In the satin weave the fine silk warp threads appear on the surface and the weft threads are covered up by the peculiar twill. Common satin is of 8-leaf twill, the weft intersecting and binding down the warp at every eighth pick, but 16 and 20 twills are also made. In the best satins a fine quality of silk is used. The gloss is partly due to hot rolling. Cheaper varieties of imitation satin are made with a cotton weft. Sateen is made from mercerized cotton. Satins are dyed to many colors and are sold under trade names. In industry they are used chiefly for linings and trimmings.

**Satinee.** The wood of the tree *Ferolia guianensis*, of the natural order *Rosaceae*, native to tropical America, particularly to the Guianas. The color of the wood is reddish brown. It has a fine grain, is fairly hard, and takes a lustrous polish. The weight is 54 lb. per cu. ft. It is used for fine cabinetwork.

**Scandium.** A metallic element, symbol Sc, found chiefly in the mineral Thortveitite, $(ScYt)_2Si_2O_7$, and in wolframite. It occurs also in small quantities in a wide variety of minerals but has as yet no commercial application because of the difficulty of extraction.

**Scheelite.** An ore of the metal tungsten, occurring usually with quartz in crystalline rocks associated with wolframite, fluorite, cassiterite, and some other minerals. It is found in various parts of the United States, Asia, and Europe. Scheelite is Calcium tungstate, $CaWO_4$, containing theoretically 80.6 per cent of tungsten trioxide and 19.4 lime. It is called Powellite when it contains some molybdenum to replace a part of the tungsten. It occurs massive granular or in crystals, with a specific gravity of 6.0 and a hardness of 4.5 to 5. Its color is white, yellow, brown, or green, with a vitreous luster. High-grade scheelite is used directly for adding tungsten to steel.

**Scouring abrasive.** Natural sand grains or pulverized quartz employed in scouring compounds and soaps, buffing compounds, and metal polishes. The Federal specifications require that the

abrasive grains used in grit cake soap and scouring compounds shall all pass a No. 100 screen, that the grains for scouring compounds for marble floors must all pass a No. 100, and 95 per cent pass a No. 200 screen. For ceramic floors 90 per cent must pass a No. 80, and 95 per cent must pass a No. 60 screen. Very fine air-floated quartz is employed in metal polishes, and all grains pass a 325-mesh screen.

**Screw stock.** A common machine-shop term for soft steel with free-cutting qualities used for screws and small turned parts made in the screw machine. It usually contains a larger percentage of sulphur than ordinary soft steel. Sulphur makes steel hot short, or brittle, at red heat, and reduces the tensile strength, but it aids machinability and is called for in steel for simple parts where strength is not important. S.A.E. specifications for screw stock call for 0.08 to 0.155 per cent of sulphur, 0.09 to 0.13 per cent of phosphorus, 0.60 to 0.90 manganese, and up to 0.25 per cent of carbon. High-manganese screw stock is an open-hearth, high-sulphur steel in the medium-manganese class having good cutting and excellent casehardening properties and higher strength. A grade of manganese screw stock under the name of Ryco is marketed by Joseph T. Ryerson & Son, Inc., having a tensile strength of 90,000 lb. per sq. in. and elongation of 20 per cent. Silcut steel is a free-cutting steel produced by W. T. Flather, Ltd. Super-cut steel, of the Union Drawn Steel Company, is a high-sulphur, Bessemer, cold-drawn steel with tensile strength up to 100,000 lb. per sq. in., elongation 18 per cent, and hardness 196 Brinell. Free-cutting steels are produced by almost all steel mills, containing sulphur, selenium, zirconium, lead, or other elements. These steels include free-cutting stainless steels. The name Screw stock also refers to free-cutting brass rod containing a small percentage of lead.

**Seal oil.** An oil obtained by steam extraction from the blubber of the oil seal, *Phoca vitulina*. The industry centers around South Georgia with the whale-oil industry. Seal oil is used in lubricating and cutting oils. It has a saponification value as high as 195 and an iodine value up to 150. It contains palmitic and other acids.

**Selenium.** An elementary metal, symbol Se, found native in cavities in Vesuvian lavas and, in combination with sulphur, in copper and iron pyrites. It is produced as a by-product in copper refining. Like sulphur it exists in various forms, having six allotropic forms. Amorphous selenium is a finely divided brick-red powder with a specific gravity of 4.26. Semicolloidal red amorphous selenium is a blood-red solution. Vitreous selenium forms a brownish-black, brittle, glassy mass with a specific gravity of 4.28. Red and gray crystalline forms are also possible. Metallic selenium is made by fusing the vitreous variety and cooling slowly. The specific gravity of the metal is 4.82, and melting point about 215°C. Selenium is odorless and tasteless, but the vapor has a putrid odor. It boils at 690°C. and burns with a purple flame.

The peculiar photoelectric properties of selenium were discovered in 1873. It changes electrical resistance when exposed to light. Ordinary fused or vitreous selenium is a poor conductor of electricity but, when annealed by heating, it takes a crystalline form and its electrical resistance is reduced, and it also becomes susceptible to changes in light. The change of electric conductivity is instantaneous, even the light of small lamps having a marked effect. It is used for light-measuring instruments and for electric eyes. The change in resistance varies directly as the square of the illumination.

Selenium is also used in steels to make them free machining; selenium steels are not as susceptible to corrosion as those with sulphur and are stronger. It is also used in glass as a decolorizer and produces the only pure red color for vitreous enamels and ruby glass. The pigment is a combination with cadmium sulphide. Selenium is also used as an accelerator in rubber and to increase abrasion resistance. In copper alloys selenium improves machinability without hot shortness. Selenium copper is a free-cutting copper containing about 0.50 per cent of selenium. It machines easily, and the electrical conductivity is nearly equal to that of pure copper. The tensile strength of annealed selenium copper is about 30,000 lb. per sq. in. Commercial selenium is a blackish powder 99 per cent pure. Vandex is a trade name of R. T. Vanderbilt Company for selenium used

as a rubber vulcanizer. Selenium as a pigment for glass is in the form of the black powder Barium selenide, $BaSeO_3$, or as Sodium selenite, $Na_2SeO_3$.

**Semisteel.** A cast iron made by adding steel scrap to the charge in the cupola. Low-carbon steel is used in the form of plates, bar ends, and rail croppings. The amount of steel varies from 15 to 40 per cent, the lower quantities for light work and the higher for heavy castings. The function of the steel scrap is to reduce total carbon in the iron and eliminate the planes of weakness produced by graphite flakes. A semisteel containing 25 per cent of steel scrap has a tensile strength above 30,000 lb. per sq. in. The weight is 0.270 lb. per cu. in. Tensile strengths as high as 40,000 lb. per sq. in. are obtained without great reduction in the casting and machining qualities. When annealed at a temperature of about 800°F., semisteel castings become soft, with considerable ductility, but lose from 25 to 35 per cent of the tensile strength. Semisteel has at times had a bad reputation because of the practice of employing miscellaneous scrap or junk steel, giving an irregular and unreliable product. Semisteel made by the addition of steel of known chemical content such as rail croppings, however, is a superior product and valued for rolls and large machine frame castings. See also High-test cast iron.

**Serpentine.** A mineral of the theoretical formula $3MgO \cdot 2SiO_2 \cdot 2H_2O$, containing 43 per cent of magnesium oxide. It is used for building trim and for making ornaments and novelties. The chips are employed in terrazzo and for roofing granules. Actually, the stone only rarely approaches the theoretical formula, and usually contains 2 to 8 per cent of iron oxide with much silica and alumina. See also Olivine. It has an asbestoslike structure. The attractively colored and veined serpentine of Vermont is marketed under the name of Verde antique. Antigorite is a form of serpentine found in California which has a platy rather than a fibrous structure.

**Shale.** A rock formed by mud or clay consolidated under pressure. It is fine-grained and has a laminated structure, and

is largely composed of silica and alumina with various impurities, often colored by oxides of iron. Unlike sandstones, shales have little porosity, but some shales contain mineral oils and form a future supply of oils. Shale is used with limestone in making portland cement. Slate is another form of shale. Bituminous shale was originally called Boghead coal in England, and Torbane mineral in Scotland. In Germany, Oil shale, after the extraction of the oil, is ground and calcined with limestone to produce cement.

**Shale oil.** An oil obtained from the porous oil-bearing shales found in many parts of the world. They are mined for oil recovery in France, Great Britain, Austria, United States, Serbia, and Australia, and occur in great quantities in Colorado, Argentina, and in other countries. Shale oil in the crude state is dark green to brown in color, and has a specific gravity of 0.850 to 0.950. The oil is obtained by distillation, the yield varying from almost nothing up to 100 gal. per ton. Scotch shales give an average yield of 24.5 gal. of crude oil and 35.7 lb. of ammonium sulphate per short ton. The shale occurs in strata and is mined like coal. It is a gray to black mineral with a laminated fracture. The oil contains more unsaturated constituents than petroleum. The products obtained by refining the crude oil include gasoline 10 per cent, illuminating and fuel oils 49 per cent, lubricating oils 7 per cent, and paraffin wax 9 per cent. It is estimated that there are 2,000 sq. mi. of oil shale lands in the state of Colorado alone, with a total of 38 billion tons of oil-bearing shale available.

**Shark leather.** A durable nonscuffing leather used for book bindings, hand bags, and fancy shoes, made from the skin of sharks. The shark is a mammal with a skin unlike fish skin. When tanned, the surface is hard, the epidermis thicker than cowhide, and the long fibers lie in a cross weave. The shark is split on the back instead of the belly as in cowhides, and the skins measure from 3 to 20 sq. ft., averaging 10 sq. ft. The hard denticle, called the shagreen, is usually removed, after which the leather is pliable but firm, the exposed grain not pulling out. Shagreen leather is a hard, strong leather with the grain side

covered with globular granules made to imitate the sharkskin. Eastern shark leather has a deep grain with beautiful markings. Olcotrop leather, from a species of shark, has a smooth, fine grain with regular markings. Galuchat leather, or Pearl sharkskin, is from the Japanese ray. It is used for trim on pocketbooks. Boroso sharkskin, Rousette leather, or Morocco leather, is from a small shark of the Mediterranean, but the name is also applied to a vegetable-tanned Spanish goatskin on which a pebbly grain is worked up by hand boarding. It is now made from ordinary goatskin by embossing. Most of the sharkskin comes from sharks caught in the Gulf of Mexico.

**Sheepskin.** The skin of numerous varieties of sheep, employed for fine leather for many uses. The best sheepskins come from the sheep yielding the poorest wool. When the hair is short, coarse, and sparse, the nourishment goes into the skin. The merino types having fine wool have the poorest pelts; wild sheep and the "low-wool," "cross-breds," and others of China and India have close-fibered firm pelts comparable with goatskins. The lambs grown in the mountains of Wales, Scotland, and the Western United States also furnish good skins. Sheepskins are tanned with alum, chrome, or sumac. The large and heavy skins from Argentina and Australia are often split, and the grain side tanned in sumac for book-binding and other goods; the flesh side is tanned in oil or formaldehyde and marketed as chamois. The fine-grained sheepskins from Egypt, when skived and specially treated, are known as Mocha leather.

**Shellac.** A product of the *Tachardia lacca*, an insect which lives on the banyan and other trees of India. The female insect exudes a resinous substance which encloses the eggs. The twigs, with the attached resin, are sold as Stick-lac. Crude stick-lac is crushed and washed to remove dirt and woody fiber, and the Lac-dye extracted. The resulting product, Seed-lac, is melted and squeezed through cloth, yielding shellac. Lac-dye was once an important dyestuff, giving about the same color as cochineal but not as strong. It is now replaced by synthetics. Commercial shellac comes from India and Burma and, when pure, varies

from pale orange to lemon-yellow in color, but the color of commercial shellac may be from a high content of common rosin. White shellac is made by bleaching with alkalies. Garnet lac is the material with the lac-dye left in. Color may also be balanced with pigments. Orange shellac contains up to 1 per cent of powdered orpiment, and the yellow may have smaller quantities. Shellac originally contained about 75 per cent of resin, 6 coloring matter, and 6 wax. Hard lac is prepared by removing about 20 per cent of the soft constituents by alkali extraction. Shellac is graded by color and by its freedom from dirt. The first grade contains no pine rosin, but other grades may contain up to 12 per cent. Cut shellac is shellac with usually 25 lb. of rosin to 100 lb. of dry shellac, dissolved in alcohol. Shellac is used in adhesives, varnishes, insulating compounds, and in some molding compounds. Shellac plastics, usually for electrical purposes, are sold under trade names such as Electrose, of the Insulation Mfg. Company, and Harvite, of the Siemon Company.

**Shock-resistant steels.** A rather general name for steels used for tools that are required to withstand much pounding. There are two general types. One type contains chromium, vanadium, and a small amount of molybdenum, with usually fairly high manganese; the other type contains up to 2 per cent of silicon, with usually some molybdenum. The silicon steels are used for pneumatic tools and for such purposes as coining dies. See Silicon steel. A steel of the Ludlum Steel Company, called Shoe die steel, for cutting block dies, or Clicker dies, for cutting leather and paper, contains 0.70 per cent of chromium, 0.35 molybdenum, 0.60 manganese, and 0.53 carbon. MSM steel, of A. Milne & Company, for punches, chisels, and shear blades, has 0.50 carbon, 2.0 silicon, 0.70 manganese, and 0.25 molybdenum. Ludlum No. 602 steel, for pneumatic tools, has 0.48 carbon, 0.70 manganese, 1.70 silicon, 0.40 molybdenum, and 0.12 vanadium. See Seminole steel.

**Shoddy.** The shredded and recovered wool of old cloth. It is either manufactured directly into new fabric or is mixed with new fibers. The word has an opprobrious signification

in the United States, and the name is therefore never used to designate the many fabrics made from shoddy wool. Extract wool is shoddy wool that is recovered by dissolving out the cotton fibers of the old cloth with sulphuric acid. Short fibers of shoddy, less than ½ in., obtained from shredding closely felted cloth, are known as Mungo fibers. They are used in woolen blends to obtain a napped effect.

**Siderite.** An ore of iron which has commercial importance in Great Britain, where it is the chief source of the metal. It is found in Staffordshire, Yorkshire, and Wales, and in the United States in Pennsylvania and Ohio. It is an Iron carbonate, $FeCO_3$ containing theoretically 48.2 per cent of iron, or it may be hydrated ferric oxide $2Fe_2O_3 \cdot 3H_2O$, with about 42 per cent of iron. It usually occurs granular, or compact and earthy. Its specific gravity is 4.5 to 5, and the hardness is 3.5 to 4. The color is light to dark brown, with a vitreous luster. It often is impure, with a mixture of clay materials or forming stratified bodies with coal formations. It is also known as Carbonate ore, Ironstone, and as Spathic iron ore. Impure forms mixed with clay and sands are called Clay ironstones, Black band, and Niggerhead ores. The Ironstone and black-band ores are the important ores of England and Scotland, but there is only a slight usage of carbonate ore in the United States. See Iron ores.

**Silex.** The original name for silica, but now applied to a finely ground white tripoli employed as an inert filler in paints. Tripoli containing iron oxide is not suitable for this purpose. Much Illinois fine-grained tripoli is used for paint filler. Pulverized flint from Belgium, used for tube-mill lining, is also known as Silex. In both cases the product is nearly pure silica.

**Silica.** A mineral of the composition $SiO_2$, Silicon dioxide, which is the most common of all materials, and in the combined and uncombined states is estimated to form 60 per cent of the earth's crust. Many sands, clays, and rocks are largely composed of silica. Silica is the weakest of the inorganic acids, but it forms definite salts with bases. When pure, silica is colorless to white. It is either crystallized or amorphous. It is insoluble

in water when anhydrous and is also insoluble in all acids except hydrofluoric. Crystallized silica in the form of quartz has a hardness of 7 on the Moh scale and a specific gravity of 2.65. Amorphous "Silica glass" has a density of 2.21. See Quartz. Pure fused silica has a melting point of 1750°C., but softens slightly at 1400°C. In chemical and heat ware it is used up to 1100°C. The coefficient of expansion is very low, 0.00000054 per deg. C. Vitreous silica is a name sometimes used for silica glass of high transparency employed for camera lenses.

Fused silica is used for chemical parts, especially where resistance to sulphuric acid is required. Silica has many other industrial uses, among which are the manufacture of paints, glass, ceramics, and cements, and for abrasives and building stones. See Silex. Silica flour, made by grinding sand, is used as a facing sand for molds. One large machine-tool foundry uses 50 parts of silica flour to 220 parts of sand and 10 parts of linseed oil. It is also employed for making flooring blocks. An acid-resistant industrial flooring of the Johns-Manville Company contains 50 per cent silica flour, 32 per cent silica sand, and 18 per cent asphalt. Pulverized silica, made from crushed quartz, is used to replace tripoli as an abrasive. Silica aerogel is a fine, white, semitransparent silica powder, the grains of which have a honeycomb structure, giving extreme lightness. It weighs 2.5 lb. per cu. ft. and is used as an insulating material in walls of refrigerators, as a filler in molding plastics, and as a light filler in paints to give a flattening effect. It is produced by treating sandstone or sand with caustic soda to form sodium silicate (see Water glass), and then treating with sulphuric acid to form a jellylike material called Silica gel. This material is then washed with water and alcohol. Santocel is a trade name of the Monsanto Chemical Company for this material. Silicon monoxide, SiO, does not occur naturally but is made by reducing silica with carbon in the electric furnace and condensing the vapor out of contact with the air. It is lighter than silica, having a specific gravity of 2.24, and is less soluble in acid. It is a brown powder valued as a pigment for oil painting as it takes up a higher percentage of oil than ochres or red lead. Monox is a trade name for silicon monoxide.

**Silicon.** One of the nonmetallic elements, symbol Si. It is used in iron, steel, and in nonferrous metals for deoxidation of the molten metals and to give hardness and other characteristics. Its melting point when pure is about 2615°F., but it readily dissolves in molten metals. It is never found free in nature, but combined with oxygen it forms silica, $SiO_2$, one of the most common substances in the earth. Silicon can be obtained in three modifications. Amorphous silicon is a brown-colored powder with a specific gravity of 2.35. It is fusible and dissolves in molten metals. When heated in the air, it burns to form silica. Graphitoidal silicon consists of black glistening spangles, and is not easily oxidized and not attacked by the common acids, but is soluble in alkalies. Crystalline silicon is obtained in dark, steel-gray globules or six-sided pyramids. It is less reactive than the amorphous form, but is attacked by boiling water. All these forms are obtainable by chemical reduction. Silicon is an important constituent of commercial metals. Molding sands are largely silica, and silicon carbides are used as abrasives. Commercial silicon is sold in the graphitoidal flake form, or as ferrosilicon, and silicon-copper. The latter forms are employed for adding silicon to iron and steel alloys. Commercial Refined silicon contains 97 per cent of pure silicon and less than 1 per cent of iron. It is used for adding silicon to aluminum alloys and for fluxing copper alloys. See Aluminum-silicon alloys.

**Silicon-aluminum.** A hardener alloy which is a silicon-rich aluminum alloy used for making additions of silicon to aluminum alloys in the foundry. A 50–50 silicon-aluminum marketed by Alloys and Products, Inc., has a melting point of 1920°F. but is soluble in aluminum at 1275°F. It comes in "pyramid waffle" form for breaking into small lumps. Silicon-aluminum-iron alloy is used as a deoxidizing agent in making iron and steel alloys and to increase the density of steel. An alloy marketed by the Vanadium Corporation of America under the name of Alsifer contains 40 per cent of silicon, 20 aluminum, and 40 iron. The aluminum and silicon are in the form of an aluminum silicate which gives a slag that is eliminated during the teeming of the

steel, and the alloy does not remain in the final steel. Alsimin is a similar alloy of the Usines Electriques de la Lonza.

**Silicon bronze.** A name applied to two classes of copper alloys. One of these is a copper, or nearly pure copper, fluxed with silicon, in which little or no silicon remains in the final metal. This material is used for strong electric wires and has high strength and resistance to corrosion. A standard alloy of this class contains 98.55 per cent of copper, 1.40 tin, and 0.05 silicon. The tensile strength, hard drawn, is 92,000 lb. per sq. in. The second class of alloy contains a considerable amount of silicon and may have nickel, tin, and other elements. This type of alloy usually depends for hardness on the formation of silicides of nickel or iron. These alloys can be heat-treated and age-hardened.

Phono bronze, or Phono electric alloys, is the trade name of a group of copper alloys of the Bridgeport Brass Company containing about 1.25 per cent of tin and small amounts of silicon and cadmium. The tensile strength of the wire is up to 100,000 lb. per sq. in., and of the hard-rolled sheet 75,000 lb. per sq. in. It is wear resistant and corrosion resistant. The electrical conductivity of the various grades varies from 14 to 80 per cent that of copper. See also Conductivity bronze. Duronze, of the same company is a high-silicon copper alloy in sheet and rod form and for forgings. The annealed rod has a tensile strength of 42,000 lb. per sq. in., with elongation of 40 per cent; the hard-drawn metal has a strength of 90,000 lb. per sq. in. Cusiloy A, of the Scovill Manufacturing Company, has 95.5 per cent of copper, 3 silicon, 1 iron, and 0.5 tin. The annealed wire has a tensile strength of 60,000 lb. per sq. in. and elongation of 50 per cent. It is marketed in various forms. An alloy known as Tetmejer contained 2.75 per cent of silicon, 5 to 10 aluminum, some iron, and the balance copper. Another bearing bronze, called Vulcan bronze, contained 1 per cent of silicon, with iron and nickel. Tombasil, an alloy developed in Germany and marketed by the Ajax Metals Company, is essentially tombac metal with the addition of silicon. It can be die-cast or sand-cast, and is used for bearings. The tensile strength is 65,000 lb. per sq. in., elongation 15 per cent, and Brinell hardness 135. P.M.G. metal, of Vickers-Armstrong,

Ltd., has 2 per cent of iron, 3 to 4 silicon, 2 zinc, and the balance copper. The forged metal has a tensile strength of 94,000 lb. per sq. in., elongation of 17 per cent, and Brinell hardness of 153.

Herculoy 418, of Revere Copper & Brass, Inc., contains 3 to 3.25 per cent of silicon and 0.50 tin. The tensile strength is from 60,000 to 125,000 lb. per sq. in. in the commercial rod. Herculoy 420, for hot-working, contains 3 per cent of silicon and 1.0 manganese. The tensile strength is up to 100,000 lb. per sq. in.

Silicon-copper alloys containing also zinc are used for die castings, bearing metals, and general strong castings. They may be called also Silicon brass, although this name properly refers to the alloys with considerable zinc and small amounts of silicon. The alloys known in Federal specifications as Copper-silicon alloy contain 5 per cent of zinc and 1 to 5 per cent of silicon, with some iron, tin, and manganese. They are used for castings or wrought parts. A grade of Olympic bronze, of the Chase Brass & Copper Company, contains 3 per cent of silicon and 1 zinc. The tensile strength is from 56,000 to 110,000 lb. per sq. in. and elongation 5 to 65 per cent. Olympic bronze G contains 22 per cent of zinc and 1 silicon, with the balance copper. It is a strong Silicon brass, and the annealed sheet has a strength of 65,000 lb. per sq. in., with elongation of 50 per cent. Doler-brass, of the Doehler Die Casting Company, is a silicon brass for die castings. A group of copper-silicon-manganese alloys is produced by the American Brass Company under the name of Everdur metal, originally patented by Charles Jacobs and called Jacobs' alloy. Everdur 1000 for castings contains about 94.9 per cent of copper, 4 silicon, and 1.1 manganese. The tensile strength, cast, is 45,000 lb. per sq. in. and elongation 15 per cent. The alloys combine high strength and toughness with acid and corrosion resistance. The wrought alloys have physical characteristics similar to those of mild steel. The hard-drawn rods have a minimum tensile strength of 70,000 lb. per sq. in. The electrical conductivity of the cast metal is 7 per cent that of copper, and of the hard wrought metal 12 per cent that of copper. A European alloy, under the name of Kuprodur, containing 0.5 per cent of silicon, 0.75 nickel, and the balance copper, has good strength at elevated temperatures and is used for locomotive firebox plates.

**Silicon carbide.** A bluish-black crystalline artificial mineral of the composition SiC, having a hardness of 9.5 on the Moh scale, and used as an abrasive in the form of powder, paper, wheels, and hones. It is also used as a refractory material, being bonded with clays or held together with its own crystals by a method of recrystallization. See Refrax. Silicon carbide is made by fusing sand and coke with sawdust, using salt as a flux. The temperature used is just above 4000°F. It was discovered in 1891 by E. G. Acheson. The specific gravity is 3.12 to 3.20. As a refractory it will withstand temperatures up to about 4200°F., at which point it decomposes. Pure silicon carbide should contain 70 per cent of silicon and 30 of carbon, but the commercial grades contain less silicon and have small amounts of iron oxide. Unlike aluminum oxide, the crystals are large, and it is crushed to make the small grains required for abrasive purposes. It is harder than aluminum oxide, and is used for the hardest types of grinding wheels. The standard grain sizes are the same as those for aluminum oxide. For polishing granite sizes 70 to 90 are used; for polishing glass lenses sizes 180 to 600 are employed. Silicon carbide as an abrasive and refractory is sold under a great variety of trade names. Carborundum is the name of the Carborundum Company for a silicon carbide. Other silicon carbides are Carbora, Carborite, Carbolite, Carbolox, Mimico, Carbobrant, Carbicon, Corex, Silexon, Crystolite, Sterbon, Storalon, Natalon, Natrundum, Lotens, Calcinite, Idilon, Electrolon. Carbex is a silicon carbide firebrick made by the General Refractories Company. Crystolon, of the Norton Company, is the name of an abrasive and a refractory.

**Silicon-copper.** An alloy of silicon and copper used for adding silicon to copper, brass, or bronze, and also employed as a deoxidizer of copper and for making hard copper. Silicon alloys in almost any proportion with copper, and is the best commercial hardener of copper. A 50–50 alloy of silicon and copper is hard and extremely brittle and black in color. A 10 per cent silicon, 90 per cent copper alloy is as brittle as glass; in this proportion silicon-copper is used for making the addition to molten copper to produce hard, sound copper castings of high strength. The

resulting copper alloy is easy to run in the foundry and does not dross. Silicon-copper grades in 5, 10, 15, and 20 per cent of silicon, are also marketed, being usually sold in slabs notched for breaking into smaller sections for adding to the melt. A 10 per cent silicon-copper melts at 1500°F., and a 20 per cent alloy melts at 1152°F.

**Silicon iron.** An Acid-resistant cast iron containing a high percentage of silicon. When the amount of silicon in cast iron is above 10 per cent, there is a notable increase in corrosion and acid resistance. The acid resistance is obtained from the compound $Fe_3Si$, which contains 14.5 per cent of silicon. The usual amount of silicon in acid-resistant castings is from 12 to 15 per cent. The alloy casts well but is hard and cannot be machined. These castings usually contain 0.75 to 0.85 per cent of carbon; amounts in excess of this decrease the acid resistance. Too much carbon also separates out as graphite in silicon irons causing faulty castings. Increasing the content of silicon in iron reduces the melting point progressively from 1530°C. for pure iron to 1250°C. for iron containing 23 per cent of silicon. A 14 to 14.5 per cent silicon iron has a silvery-white structure, a compressive strength of about 70,000 lb. per sq. in., Brinell hardness of 290 to 350, and is resistant to hot sulphuric acid, nitric acid, and organic acids. Silicon irons are also very wear resistant, and are valued for pump parts and for parts for chemical machinery. They are marketed under many trade names. Tantiron, of the Bethlehem Foundry and Machine Company, contains 14 to 15 per cent of silicon, 2 to 2.5 manganese, and 1 carbon. The high manganese aids the machining properties of the metal. Duriron, of the Duriron Company, contains 14.5 per cent of silicon and 1 per cent of carbon and manganese. The tensile strength is 16,000 lb. per sq. in. and weight 0.253 lb. per cu. in. Durichlor, of the same company, is a special grade of high-silicon iron resistant to hydrochloric acid. See also Durimet. Antaciron is a 14.5 per cent silicon iron of Antaciron, Inc., and Corrosiron is a similar iron of the Pacific Foundry Company. Thermisilid is the original name given by the Krupp Works to high-silicon cast iron. A heat-resistant silicon iron developed by the British Cast

Iron Research Association under the name of Silal contains only 5 per cent of silicon. It is used for stoker and furnace parts.

**Silicon-manganese.** An alloy employed for adding manganese to steel, and also as a deoxidizer and scavenger of steel. It usually contains 65 to 70 per cent of manganese and 12 to 25 per cent of silicon. It is graded according to the amount of carbon, generally 1, 2, and 2.5 per cent. For making steels low in carbon and high in manganese, silico-manganese is more suitable than ferromanganese. A reverse alloy, called Manganese-silicon, contains 73 to 78 per cent of silicon and 20 to 25 per cent of manganese, with a maximum of 1.5 per cent of iron, and a maximum of 0.25 per cent of carbon. It is used for adding manganese and silicon to metals without the addition of iron. Still another alloy is called Ferromanganese-silicon, and contains 20 to 25 per cent of manganese, about 50 per cent of silicon, and 25 to 30 per cent of iron, with only about 0.50 per cent or less of carbon. This alloy has a low melting point, which permits it to be taken readily into solution.

**Silicon-spiegel.** Also called Silico-spiegel. An alloy of silicon and manganese with iron, employed for making furnace additions of silicon and manganese to open-hearth steels. A typical analysis gives 25 to 30 per cent of manganese, 7 to 8 per cent of silicon, and 2 to 3 per cent of carbon. Both the silicon and manganese act as strong deoxidizing agents, forming a thin fusible slag, making clean steel.

**Silicon steel.** All grades of steel contain some silicon; most steels contain from 0.10 to 0.35 per cent as a residual of the silicon used as a deoxidizer. But from 3 to 5 per cent of silicon is sometimes added to increase the magnetic permeability, and larger amounts are added to obtain wear-resisting or acid-resisting properties. Silicon deoxidizes steel, and up to 1.75 per cent the elastic limit is increased without loss of ductility. Silicon steels within this range are used for structural purposes and for springs, giving a tensile strength about 75,000 lb. per sq. in. and elongation of 25 per cent. A common low-silicon structural steel contains up to 0.35 per cent of silicon and 0.20 to 0.40 carbon, but

the Structural silicon steels are ordinarily Silicon-manganese steel, with the manganese above 0.50 per cent. European silicon structural steels contain 0.80 or more per cent of silicon, with manganese above 0.50 per cent, and very low carbon. Considerable addition of silicon above 1.75 per cent increases the hardness and the corrosion resistance, but reduces the ductility and makes the steel brittle. The lower grades can be rolled, however, and silicon-steel sheet is used for electric transformer laminations. Silicon forms a chemical combination with the metal, forming an iron silicide. The value of silicon steel as a Transformer steel was discovered by Hadfield in 1883. Silicon increases the electrical resistivity and also decreases the hysteresis loss, making silicon steel valuable for magnetic circuits where alternating current is used. Tran-Cor is a high-silicon steel produced by the American Rolling Mill Company for cores for electrical transformers. A very tough and strong tool steel for forming tools, pneumatic tools, and long punches is made with the addition of silicon and some molybdenum. Solar steel, of the Carpenter Steel Company, has 1 per cent silicon, 0.50 molybdenum, 0.40 manganese, and 0.50 carbon. It is water hardening, and has a breaking strength of 323,000 lb. per sq. in., with elongation of 4.5 per cent. Silman steel, of the Vanadium Alloys Steel Company, has 2.10 per cent of silicon, 0.25 chromium, 0.30 vanadium, 0.85 manganese, and 0.55 carbon. The silicon gives it wear-resistant properties making it suitable for shear blades and punches; the other alloying elements give toughness and resistance to fatigue. These steels are often referred to as Shock-resistant steel. See Ludlum 602 steel. Electrical steel, or Electric sheet, is sheet steel for armatures and transformers, in various grades from 1 to 4.5 per cent of silicon. As a casting metal, steel or iron containing considerable amounts of silicon makes sound castings without blow holes, as the silicon aids in the deoxidation of the molten metal. The silicon-manganese steels with silicon up to 2 per cent and up to about 1 per cent of manganese are tough, strong, and wear resistant, and are useful for gears, cams, and rolls. A steel with 1.5 silicon, 0.50 manganese, and 0.40 carbon has a tensile strength of 110,000 lb. per sq. in. and elongation 18 per cent. S.A.E. steel 9255 has 2 per cent silicon and 0.75 manganese.

Silicon, up to 1 per cent, is used in nickel and chromium steels to increase hardness and to resist oxidation at high temperatures.

**Silk.** The fibrous material in which the silkworm, or larvae of the moth, *Bombyx mori*, envelops itself before passing into the chrysalis state. Silk is closely allied to cellulose and resembles wool in structure, but unlike wool it contains no sulphur. The natural silk is covered with a wax or silk glue which is removed by scouring in manufacture, leaving the glossy Fibroin, or raw-silk fiber. The fiber is unwound from the cocoon and spun into threads. Each cocoon has from 2,000 to 3,000 yd. of thread. One pound of raw silk is obtained from 2½ lb. of cocoons. The chief silk-producing countries are China, Japan, India, Italy, and France. Japanese raw silk is shipped in bales of 100 kin., 133⅓ lb. European silk bales weigh 220.5 lb., and Canton bales 106⅔ lb. The "conditioned weight" in shipping is the dry weight plus 11 per cent of moisture. A "Book" is a bundle of Asiatic silk containing 50 to 60 skeins, about 4 to 4.5 lb. Floss silk is a soft silk yarn practically without twist, or is the loose waste silk produced by the worm when beginning to spin its cocoon. Hard silk is thrown silk from which the gum has not been discharged. Soft silk is thrown silk yarn, degummed, dyed or undyed. Souple silk is dyed skein silk from which little gum has been discharged. It is firmer but is less lustrous. Organzine silk is from the best grade of cocoons. Marabout silk, used for making imitation feathers, is a white silk, twisted, and dyed without discharging the gum.

In China the cultivation of the silkworm is claimed to date back to 2640 B.C. Silk was first woven in Rome about 50 B.C. The eggs of the silkworm were smuggled into Europe in the year 552. Sericulture, or silkworm culture, is a highly developed industry. The larvae, which have voracious appetites, are fed on mulberry leaves for 24 days, after which they complete their cocoon in 3 to 4 days. In from 7 to 10 days these are heated to kill the chrysalis to prevent bursting of the shell. The reeling is done by hand and by machine. Wild silk is from a night peacock moth which does not feed on the mulberry. It is coarser and stronger, but darker in color and less lustrous. Tussah silk is a variety of

wild silk from South China and India. Byssus silk is a long fiber from a mussel of Sardinia and Corsica which spins the thread to attach itself to rocks. The fiber is golden-brown, soft, lustrous, and elastic, and not dissolved by acids or alkalies. It was formerly used for fine garments but is no longer obtained commercially. Canton silk is soft and fluffy, but is greenish in color and lacks firmness. It is from the *Bombyx textor*, and is used for weft yarns and in crepes. This silk when grown in India and known as Indian silk is the finest of all silks with fibers 0.0004 in. compared with 0.001 in. for Japanese silk. Japan now produces 75 per cent of the silk of the world, mostly from a cultivated moth of the tussah variety, *Antheria yama mai*. Shantung silk is from a tussah moth, *Antheria pernyi* which feeds on oak leaves.

**Silver.** A white metal, symbol Ag, very malleable and ductile, and classed with the precious metals. It occurs in the native state, and also combined with sulphur and chlorine. Copper, lead, and zinc ores frequently contain silver; about 70 per cent of the production of silver is a by-product of the refining of these metals. Mexico and the United States produce more than half of the silver of the world. Although nearly 90 per cent of the silver produced in Arizona comes from copper ores, most of that produced in California is a by-product of gold quartz mining. It is profitable to extract the silver from lead ores having only 3 oz. per ton. Silver is the whitest of all the metals and takes a high polish, but easily tarnishes in the air because of the formation of a silver sulphide. It does not corrode. It has the highest electrical and heat conductivity. The specific gravity is 10.7, and the melting point is 1762°F. It is soluble in nitric acid and in hot sulphuric acid. The tensile strength of cast silver is 41,000 lb. per sq. in. and Brinell hardness 59. The metal is marketed on a troy-ounce value.

The standard grades of commercial silver are Fine silver, Sterling silver, and Coin silver. Fine silver is 99.9 per cent pure. Coin silver is usually an alloy of 90 per cent silver and 10 copper. The ratio of value of silver to gold has remained for nearly 2,500 years as 15.5 and 16 to 1. It is used for coinage, silverware, orna-

ments, silver plating, for alloying with gold, and in the form of its salts for photography and other uses. Electrical contacts are made frequently of fine silver and also of sterling silver, but mostly of coin silver since the higher proportion of copper hardens the metal and gives greater wear resistance. Silver plating is sometimes done with a Silver-tin alloy containing 20 to 40 parts silver and the remainder tin. It gives a plate having the appearance of silver but with better wear resistance. Silver-clad sheet, made of a cheaper nonferrous sheet with a coating of silver rolled on, is used for food-processing equipment. It is resistant to organic acids but not to products containing sulphur. Doré metal is crude silver metal containing gold.

**Silver nitrate.** Formerly known as Lunar caustic. A colorless, crystalline, poisonous, and corrosive material of the composition $AgNO_3$ made by dissolving silver in nitric acid. It is used for silvering mirrors, for silver plating, and in indelible inks. It is an active oxidizing agent. Silver chloride, AgCl, is a white granular powder used in silver plating solutions. This salt of silver and other halogen compounds of silver, especially Silver bromide, AgBr, are used for photographic plates and films. The image cast on the plate by the lens breaks down the compound in proportion to the intensity of the light. Silver sulphide, $Ag_2S$, is a gray-black, heavy powder used for inlaying in metal work. Silver potassium cyanide, $KAg(CN)_2$, is a white, crystalline, poisonous solid used for silver plating solutions.

**Silver solder.** High-melting-point solder employed for soldering joints where more than ordinary strength is required. Most silver solders are copper-zinc brazing alloys with the addition of silver, and the soldering is done with a blow torch. Cadmium may also be added to lower the melting point. Silver solders do not necessarily contain zinc, however, and may be alloys of silver and copper in proportions arranged to obtain the desired melting point and strength. A silver solder with a relatively low melting point contains 65 per cent of silver, 20 copper, and 15 zinc. It melts at 1280°F., has a tensile strength of 64,800 lb. per sq. in., and elongation of 34 per cent. The electrical conductivity is only 21 per cent that of pure copper. A solder

melting at 1400°F. contains 20 per cent silver, 45 copper, and 35 zinc. Any tin present in silver solders makes them brittle; lead and iron make the solders difficult to work. Silver solders are malleable and ductile and have high strength. They are also corrosion resistant and are especially valuable on food machinery and apparatus where lead is objectionable. They can be employed to braze stainless steels. Sil-Fos is the trade name of Handy and Harman, for a phosphor-silver brazing solder with a melting point of 1300°F. It contains 15 per cent of silver, 80 copper, and 5 phosphorus. Lap joints brazed with Sil-Fos have a tensile strength of 30,000 lb. per sq. in. The phosphorus in the alloy acts as a deoxidizer, and the solder requires little or no flux. It is used for brazing brass, bronze, and nickel alloys. See also Solder.

**Sisal.** The fibers obtained from the large leaves of the sisal plant, *Agave sisalana*, and the henequen plant, *A. fourcroydes*, employed for making rope, cordage, and sacking. About 80 per cent of all binder twine is made from sisal. The agave plant grows chiefly in Mexico, and most of the sisal hemp comes from Yucatan. Yucatan sisal, or Henequen, is from the henequen plant and commands a higher price. The fiber is obtained by scraping off the fleshy parts of the leaf, washing, and drying. The fibers are not as long or as strong as those of Manila hemp and swell when wet, but they are soft and are preferred for binder twine either alone or mixed with Manila hemp. Sisal fiber is also used instead of hair in cement plasters for walls. Agave fibers from other varieties of the plant are used for various purposes, notably Tampico, from the *A. rigida*, which yields a stiff, hard, but pliant fiber employed for brushes, and Istle, a similar stiff brush fiber. The true istle, however, comes from Istle-grass, *Bromelia sylvestris*, a tropical plant.

**Slag.** The molten material that is drawn from the surface of iron in the blast furnace. Slag is formed from the earthy materials in the ore and from the flux. Slags are produced in the melting of other metals, but iron blast-furnace slag is usually meant by the term. Slag is used in cements and concrete, for roofing, and as ballast for roads. Blast-furnace slag is one of the lightest concrete aggregates available. It has a porous structure

and, when crushed, is angular. About 1,300 lb. of slag is produced for every long ton of metallic iron. It is also crushed and used for making Pozzuolan and other cements. Slag contains about 32 per cent of silica, 14 of alumina, 47 of lime, 2 of magnesia, and small amounts of other elements. It is crushed, screened, and graded for marketing. Crushed slag weighs 1,900 to 2,100 lb. per cu. yd., or about 30 per cent lighter than gravel. Honeycomb slag weighs only about 30 lb. per cu. ft. The finest grade of commercial slag is from $\frac{3}{16}$ in. to dust; the "run-of-crusher" slag is from 4 in. to dust. Basic phosphate slag, a by-product in the manufacture of steel from phosphatic ores, is finely ground and sold for fertilizer. It contains not less than 12 per cent of phosphoric acid, $P_2O_5$ and is known in Europe as Thomas slag. Foamed slag is a name used in England for honeycomb slag used for making light-weight, heat-insulating blocks. See also Slag pumice. A superphosphate cement is made in Belgium from a mixture of basic slag, slaked lime, and gypsum.

**Slate.** A shale possessing a straight cleavage. Most shales are of sedimentary origin, and their cleavage was the result of heavy or long-continued pressure. In some cases slates have been formed by the consolidation of volcanic ashes. The slaty cleavage does not usually coincide with the original stratification. Slate is of various colors, black, gray, green, and reddish. It is used for electric panels, blackboards, slate pencils, table tops, roofing shingles, floor tiles, treads, and flagstones. Slate is quarried in large blocks, and then slabbed and split. The chief slate-producing states are Pennsylvania, Vermont, Virginia, New York, and Maine. Roofing slates vary in size from 12 by 6 in. to 24 by 14 in., and from $\frac{1}{8}$ to $\frac{3}{4}$ in. in thickness, and are usually of the harder varieties. The roofing slate from coal beds is black, fine-grained, and breaks into brittle thin sheets. It does not have the hardness or weather resistance of true slate. Ribbon slate, with streaks of hard material, is inferior for all purposes. Lime impurities can be detected by the application of dilute hydrochloric acid to the edges and noting if rapid effervescence occurs. Iron is a detriment to slates for electric purposes. The average compressive strength of slate is 15,000 lb. per sq. in. and

the weight 175 lb. per cu. ft. Slate flour is ground slate used as a filler in linoleum and in caulking compounds.

**Slate-lime.** An intimate mixture of finely divided calcined slate and lime, either in the proportion of half and half, or about 60 per cent by weight of lime to 40 of calcined slate. It is employed for making porous concrete for insulating partition walls. The process consists in adding a mixture of slate-lime and powdered aluminum, zinc, or magnesium to the cement. The gas generated on the addition of water makes the cement porous. See also Aerocrete.

**Smalt.** Also called Royal blue, or Saxon blue. A deep-blue powdered glass used as a pigment. It is made by fusing cobalt oxide with silica in the presence of potassium carbonate, and contains 65 to 71 per cent of silica, 16 to 21 per cent of potash, 6 to 7 per cent of cobalt oxide, and a little alumina. It is durable but does not have good covering power. It is chiefly used in coloring blue glass or vitreous enamels.

**Smoke agents.** Chemicals used in warfare to produce an obscuring cloud or fog to hide movements. Smokes may be harmless and are then called Screening smokes, or Smoke screens, or they may be toxic and called Blanketing clouds. There are two general types of smokes, those forming solid or liquid particles, and those forming fogs or mists by chemical reaction. The first naval smoke screens were made by limiting the admission of air to the fuel in the boilers, and the first army Smoke pots of 1915 contained mixtures of pitch, tallow, saltpeter, and gunpowder. The British Smoke candles contained 40 per cent potassium nitrate, 29 pitch, 14 sulphur, 8 borax, and 9 coal dust. They gave a brown smoke, but one which lifted too easily. Incomplete burning of crude oil gives the cheapest naval smoke. White phosphorus gives a dense white smoke by burning to the pentoxide and changing to phosphoric acid in the moisture of the air. Its vapor is toxic. Sulphuric trioxide, $SO_3$, is an effective smoke producer in humid air. It is a mobile colorless liquid vaporizing at 45°C. to form dense white clouds with an irritating effect. The French Opacite is Tin tetrachloride, $SnCl_4$, a liquid

which fumes in the air. The smoke is not so dense but it penetrates gas masks and is corrosive. Sulphuryl chloride, $SO_2Cl_2$ is a liquid which decomposes on contact with the air into sulphuric and hydrochloric acids. Silicon tetrachloride, $SiCl_4$, is a colorless liquid which boils at 60°C. and fumes in the air forming a dense cloud. Mixed with ammonia vapor it resembles a natural fog. A common smoke for airplanes is Oleum. It is a solution of sulphur trioxide in sulphuric acid. The dense liquid is squirted into the exhaust manifold. Zinc smoke is made with mixtures of zinc dust or zinc oxide with various chemicals to form clouds of zinc chloride. See also Poison gases.

**Snakeskins.** The snakeskins employed for fancy leathers are in general the skins of large tropical snakes which are notable for the beauty or oddity of their markings. Snakeskins for shoe upper leathers and handbags are glazed like kid and calfskin after tanning. The leather is very thin, but is remarkably durable and is finished in natural colors, or is dyed. Python skins are widely used for ladies' shoes, pocketbooks, and belts. Regal python skins from Borneo, the Philippines, and the Malay Peninsula sometimes measure 30 ft. in length and have characteristic checked markings.

**Soap.** A cleansing compound produced by saponifying oils, fats, or greases with an alkali, depending for its action largely on a small proportion of free alkali. When caustic soda is added to fat, glycerin separates out, leaving Sodium oleate, $Na(C_{18}H_{33}O_2)$, which is soap. If an excess of alkali is used, the soap will contain free alkali, and the greater the proportion of the free alkali the coarser is the action of the soap. About half of all soap is made with tallow, 25 per cent with coconut oil, and the remainder with palm oil, greases, fish oils, olive oil, soybean oil, or mixtures. Auxiliary ingredients are used in soap to improve the color, for perfuming, as an astringent, or for abrasive or harsh cleansing purposes. Transparency usually varies with the content of coconut, palm, or olive oil. Solvents are added to industrial soaps for scouring textiles or when used in soluble oils in the metal industry. Zinc oxide, benzoic acid, and other materials are used in facial soaps with the idea of aiding complexion. Exces-

sive alkalinity in soaps dries and irritates the skin. Silicate of soda, used as a filler, also irritates the skin. Ordinary Soft soaps used as bases for Toilet soap are made with linseed and olive-oil mixtures. Linseed oil, however, gives a disagreeable odor. Soybean oil, corn oil, and peanut oil are also used. Oil for the best soaps are of the nondrying type. Soft soap of U.S.P. grade always has a therapeutic value. High-grade Soft soap for industrial use is made with coconut or palm kernel oil with caustic potash. Hand soaps may be made with Trisodium phosphate, $Na_3PO_4 \cdot 12H_2O$, known as Phosphate cleaner, or with Disodium phosphate, $Na_2PO_4 \cdot 12H_2O$, or Sodium perborate, $NaBO_3 \cdot H_2O$, known as Perborin, all of which are crystalline substances which are dissolved in water solution. Soap powder is Granular soap made in a vacuum chamber or by other special processes. Floating soaps are made light by blowing air through them while in the vats. A typical American soap contains 80 per cent mixed oils and 20 per cent coconut oil, with not over 0.2 per cent of free alkali. The wartime soap standardized in Germany in 1940 under the name of Rif has only 40 per cent fat content, with the remainder made up of sodium silicate, kaolin or clays. See also Mineral soap.

**Soapstone.** A massive variety of impure talc employed for electric panels, gas-jet tips, stove linings, tank linings, and as an abrasive. It is known in mineralogy as Steatite. It can be cut easily and becomes very hard when heated because of the loss of its combined water. The waste product from the cutting of soapstone is ground and used for the same purposes as talc powder. See Talc and Lava. Alberene stone, quarried in Virginia, is blue-gray in color. The medium hard varieties are used for building trim and for chemical laboratory tables and sinks, and the hard varieties are employed for stair treads and flooring. Virginia greenstone is a type of gray-green soapstone resistant to weathering, used as a building stone.

**Soda ash.** The common name for anhydrous Sodium carbonate, $Na_2CO_3$, which is the most important industrial alkali. For household use in hydrous crystallized form, $Na_2CO_3 \cdot 10H_2O$, it is called Washing soda, or Sal soda, as distinct from Baking

soda, which is Sodium hydrogen carbonate, or Sodium bicarbonate, $NaHCO_3$. Another grade, with one molecule of water, $Na_2CO_3 \cdot H_2O$, is the standard product for scouring solutions. Federal specifications call for this product with a total alkalinity not less than 49.7 per cent $Na_2O$. Laundry soda is this material mixed with sodium bicarbonate, with 39 to 43 per cent $Na_2O$. Soda ash is less expensive than caustic soda and is used for cleansing, for softening water, in glass as a flux and to prevent fogging, in the wood pulp industry, for refining oils, in soaps, and for other applications. It is used with lime as a flux in melting iron to increase the fluxing action of the lime, as it will carry off 11 per cent of sulphur in the slag. In Germany it is used for desulphurizing iron instead of manganese, although the cost is higher. Soda is a grayish-white to colorless lumpy substance. The crystallized variety loses half of its water of crystallization when heated slightly. Soda ash is made from sodium bicarbonate, which in turn is made by treating salt brine with ammonia and carbon dioxide, called the Solvay process. It is usually sold in two grades, of 48 and 58 per cent $Na_2O$. The 58 per cent grade is marketed as dense or light, the dense consistency being used where bulk is needed, as for glass. Purite is the trade name for sodium carbonate marketed by the Mathieson Alkali Works, Inc., for use as a fluxing agent with lime.

**Soda lime.** A mixture of hydrated lime and an alkali, used for freeing the air of carbon monoxide, and as a chemical purifying agent. It is also used in gas masks for chemical warfare. For the latter use it contains about 18 per cent of portland cement, 8 per cent of kieselguhr, and 1.5 per cent of sodium hydroxide. The cement is for the purpose of making fine granules.

**Sodium.** A metallic element, symbol Na, occurring only in the form of its salts. The most important mineral containing sodium is the chloride, $NaCl_2$, which is common salt. It also occurs as the nitrate, Chile saltpeter, as a borate in borax, and as a fluoride and a sulphate. When pure, sodium is silvery white, ductile, and melts at 204°F. The specific gravity is 0.971. It can be obtained in metallic form by the electrolysis of salt. When exposed to the air, it oxidizes rapidly and must be kept in air-

tight containers. Sodium is widely employed in industry in its salts. It can be used as a deoxidizer and desulphurizer in copper alloys. Sodium-tin, with 95 per cent of tin and 5 sodium, and Sodium-copper, are called Desulphurizing alloys.

**Sodium aluminate.** A white powder of the composition $Na_2Al_2O_4$, used as a water-softening agent with lime and soda in steam boilers. It has a melting point of 1800°C. and is soluble in water. It is made by the reaction of alumina with some source of sodium oxide such as caustic soda or soda ash, or by heating bauxite with sodium carbonate and extracting with water.

**Sodium cyanide.** A salt of hydrocyanic acid of the composition NaCN, used for carbonizing steel for casehardening, for heat-treating baths, for electroplating, and for the extraction of gold and silver from their ores. For carburizing steel it is preferred to potassium cyanide because of its lower cost and its higher content of available carbon. It contains 53 per cent of CN, as compared with 40 per cent in potassium cyanide. The nitrogen also aids in forming the hard case on the steel. The 30 per cent grade of sodium cyanide, melting at 1156°F., is used for heat-treating baths instead of lead, but it forms a slight case on the steel. Sodium cyanide is very unstable, and on exposure to moist air liberates the highly poisonous Hydrocyanic acid gas, HCN. For gold and silver extraction it easily combines with the metals, forming soluble double salts, $NaAu(CN)_2$. Sodium cyanide is made by passing a stream of nitrogen gas over a hot mixture of sodium carbonate and carbon in the presence of a catalyst. It is a white crystalline powder, soluble in water. It is usually packed in 100- and 200-lb. containers, made up in 1-oz. briquettes, 4-oz. eggs, or fused and broken. Cyanegg is the trade name of the Roessler & Hasslasher Chemical Company for 96 to 98 per cent sodium cyanide in "egg" form for casehardening steel. The melting point is 1040°F.

**Sodium ferrocyanide.** Also known as Yellow prussiate of soda. A lemon-yellow crystalline solid of the composition $Na_4Fe(CN)_6 \cdot 10H_2O$, used for carbonizing steel for casehardening. It

is also employed in paints and printing inks and for the purification of organic acids. It is soluble in water.

**Sodium hydroxide.** Known commonly as Caustic soda, and also as Sodium hydrate, and Lye. A white, massive crystalline solid of the composition $NaOH$, used for scouring and cleaning baths, for etching aluminum, in quenching baths for heat-treating steel, and in cutting and soluble oils. It has also a wide variety of other commercial uses. Sodium hydroxide is made by the causticization of soda ash or by the electrolysis of salt. The specific gravity is 2.13 and melting point 318°C. It is soluble in water, alcohol, and in glycerin. Sodium hydroxide is sold in both the liquid and a solid state on a basis of its $Na_2O$ content. Caustic potash is Potassium hydroxide, $KOH$, which has the same uses but is more expensive. Caustic potash is a white, lumpy, solid. It is soluble in water and makes a powerful cleansing bath for scouring metals. It is also used in soaps and for bleaching textiles. When used in steel-quenching baths, it gives a higher quenching rate than water alone and does not corrode the steel like a salt solution.

**Sodium nitrate.** Also called Soda niter, and Chile saltpeter. A mineral found in large quantities in the arid regions of Chile, Argentina, and Bolivia, where the crude nitrate with iodine and other impurities is called Caliche. It is used for making nitric and sulphuric acids, for explosives, as a flux in welding, and as a fertilizer. The composition is $NaNO_3$. It is usually of massive granular crystalline structure with a hardness of 1.5 to 2 and specific gravity of 2.29. It is colorless to white, but sometimes colored by impurities. It is readily soluble in water. In other parts of the world it occurs in beds with common salt, borax, and gypsum. Synthetic Chile saltpeter is made by nitrogen fixation and is marketed granulated, in crystals, or in sticks. It is colorless, odorless, has a specific gravity of 2.267 and a melting point of 316°C. It has a bitter, saline taste. Sodium sulphate, or Glauber's salt, is a white crystalline substance of the composition $Na_2SO_4 \cdot 10H_2O$, used in the manufacture of kraft paper, rayon, and in glass. When obtained from the evaporation of mineral springs, it is called Crazy water crystals. Synthetic salt

cake, used for kraft paper, is sodium sulphate made by sintering soda ash and sulphur.

**Solder.** An alloy of two or more metals used for joining other metals together by surface adhesion. A requirement is that it have a lower melting point than the metals being joined, and also have an affinity for, or be capable of uniting with, the metals to be joined. The most common solder is called Half-and-Half, or Plumbers' solder, and is composed of equal parts of lead and tin. It melts at 360°F. The weight of this solder is 0.318 lb. per cu. in., tensile strength 55,000 lb. per sq. in., and the electrical conductivity 11 per cent that of copper. Commercial half-and-half, however, usually contains larger proportions of lead and some antimony, because of the higher cost of tin. These mixtures have higher melting points, and solders with less than 50 per cent of tin have a wide melting range and do not freeze quickly. Sometimes a wide melting range is desired, in which case a Wiping solder, with 30 to 40 per cent of tin is used. Slicker solder is the best quality of plumbers' solder, containing 63 to 66 per cent of tin and the balance lead. The earliest solders were the Roman solder called Argentarium, containing equal parts of tin and lead, and Tertiarium, containing one part of tin and two of lead. Both alloys are still in use, and throughout early industrial times Tertiarium was known as Tinman's solder. Good-quality solders for electrical joints should have at least 40 per cent of solder as the electrical conductivity of lead is only about half that of tin, but conductivity is frequently sacrificed for better wiping ability, and the wiping solders are usually employed for electrical work. Soft solders should not contain zinc because of poor adhesion from the formation of oxides. Various melting points to suit the work are obtained with solders by varying the proportions of the metals. The low-melting-point solders are those that have a melting point at 230°C. or lower, and the high-melting-point solders melt at 705°C. and higher. The "flow point," at which the solder is entirely liquid, is often considerably above the melting point. Tin added to lead lowers the melting point of the lead until at 356°F., or 68 per cent tin, the melting point rises with increase in tin content until the melting

point of pure tin is reached. Solders with low melting points are obtained from mixtures of lead, tin, and bismuth; Bismuth solder is also more fluid, as the bismuth lowers the surface tension. Bismuth, however, hardens the alloy, although to a lesser extent than antimony. A Bismuth solder containing equal parts of lead, tin, and bismuth melts at 284°F. Soft solders for soldering brass and copper, especially for electrical connections, may be of tin hardened with antimony. Solder wire, marketed by the American Brass Company for this purpose, contains 95 per cent of tin and 5 antimony. Thallium may be used in high-lead solders to increase strength.

Hard solders may be any solder with a melting point above that of the tin-lead solders; more specifically they are the brazing solders, silver solders, or aluminum solders applied with a brazing torch. Spelter solders are brasses and are inclined to be brittle when applied. An S.A.E. spelter solder contains 50 to 52 per cent of copper and the remainder zinc. It melts at 1560°F. Aluminum solders may contain from 7 to 15 per cent of aluminum. Solders with nickel content are used for soldering nickel silver, and silver and gold solders are used for jewelry work. Silver solder in varying proportions is also used as a high-melting-point solder for general work. See Silver solder, Aluminum solder, Brazing metals. A standard solder with 48 per cent of tin and 52 lead melts at 360°F. A 45–55 solder melts at 465°F. Cheap solders may contain as low as 25 per cent tin, but they do not adhere well. See also Cadmium solder.

**Soluble oils.** Oils made soluble by treatment with sodium hydroxide or other alkali, either by direct mixture or by the addition of soaps to the oil. Oils, thus treated, emulsify readily because of the formation of sodium oleate and sodium palmitate and are mixed with water for use in pumping over the work being machined in rapid production machines. The presence of about 1 per cent of sulphur is important. Sulphonated lard oil is used to bring up the sulphur content. Pine oil or oil of sassafras is added to improve the odor. Cresol is added for disinfecting. Rosin or rosin oil is added to form sodium resinate to improve the cutting qualities. A typical ordinary oil mixture is 40 gal. of

water, 10 of lard oil, 2.5 lb. of soda ash, and 10 oz. of borax. Federal specifications call for a maximum of 10 per cent water, with no separation of the water in 24 hr. at 75°F. Soda water, used as a substitute for soluble oils for cooling metal-cutting tools, is made with 100 gal. of water, 18.5 lb. of soda ash, and 15.5 lb. of soap. Soluble oils are used mainly for keeping the work and cutters cool, but they also exert a lubricating action between the cutting edge of the tool and the work, thus decreasing the friction of cutting. In machines having hardened and ground steel spindles, the soluble oils are also used to lubricate the bearings because of the facility of flow and their cooling action. Their disadvantage is that they easily corrode iron and steel. See also Cutting oils, and Coolants.

**Solvents.** Liquids having the power of dissolving various materials. The usual commercial solvents for organic substances are the alcohols, ether, benzine, and turpentine, the latter two being the usual solvents for paints and varnishes containing gums and resins. Carbon bisulphide and dichlorethylene are good solvents for rubber. Amyl and other alcohols, amyl acetate, and other volatile liquids are used for quick-drying lacquers, but many synthetic chemicals are available for such use. Dioxan, a water-white liquid of specific gravity of 1.035 and composition $CH_2CH_2OCH_2CH_2O$, is a good solvent for cellulose compounds, resins, and varnishes, and is used also in Paint removers, which owe their action to their solvent power. Ethyl lactate, used as a solvent for cellulose nitrate, is a liquid with boiling point of 150°C. and specific gravity of 1.03. Octyl alcohol, a stable liquid of the composition $CH_3COOCH_2CH(C_2H_5)C_4H_9$ and boiling point of 183.5°C., has a high solvent power for nitrocellulose and resins. See also Cellosolve, Ether, Carbitol, Solox. The chlorinated hydrocarbons have powerful solvent action on fats, waxes, and oils and are used in degreasing. Water is a solvent for most acids and alkalies and for many organic and inorganic materials. Acids or alkalies that decompose the material are not solvents for the material. Solvents are used to produce a solution that can be applied, as in the case of paints, and the evaporation of the solvent then leaves the material chemically unchanged. They

may also be employed to separate one substance from another, by the selection of a solvent that dissolves one substance but not the other. They are also used in scouring solutions. Dichlorethyl ether, a yellowish liquid with a chloroformlike odor, of the composition $ClCH_2CH_2OCH_2CH_2Cl$, is a good solvent for fats and greases and is used in scouring solutions and in soaps. Dichlor-ethylene is a liquid of the composition $C_2H_2Cl_2$, specific gravity 1.278, and boiling point of about 52°C. It is used as a solvent for the extraction of fats and for rubber. Decalin, used as a solvent for resins and oils, is a liquid with a specific gravity of 0.884 and boiling point of 190°C. It is made by the hydrogenation of naphthalene.

**Sorel cement.** A magnesia cement consisting of a mixture of magnesia with a concentrated solution of magnesium chloride, or it can be prepared by adding water to a mixture of the two dry components. It has considerable strength and elasticity and is used for cementing glass and metal, for making artificial stones, and for flooring in railway cars. It can be cut and drilled easily. Sorel cement, or Oxy-chloride cement, may be mixed with fillers such as sawdust, cork, talc, or silica. The Magnesium chloride used in the mixture is a white, crystalline solid of the composition $MgCl_2$, obtained from salt brines after the extraction of the salt.

**Sorel's alloy.** A zinc-copper alloy containing iron, and out of the range of the brasses because of its high zinc content. It may contain as high as 98 per cent of zinc with 1 per cent of copper and 1 of iron, or it may have as low as 80 per cent zinc with 10 per cent copper and 10 per cent iron. It is employed for casting small statues or novelties, and is very hard and quite brittle. It cannot be rolled or drawn. It is plated with bronze and marketed as cast bronze. The alloy is prepared by melting brass of known composition and then adding the zinc and iron.

**Sound insulators.** Materials employed, chiefly in walls, for reducing the transmission of noise. Insulators are used to impede the passage of sound waves, as distinct from Isolators used under machines to absorb the vibrations that cause the sound. For

factory use the walls, partitions, and ceilings offer the only mediums for the installation of sound insulators. All material substances offer resistance to the passage of sound waves, and even the glass windows may be considered as insulators. But the term refers to the special materials placed in the walls for this specific purpose. Insulators may consist of mineral wool, hair felt, fiber sheathing boards, or simple sheathing papers. Sound insulators are marketed under a variety of trade names, such as Celotex, made from bagasse, and Fibrofelt, made from flax or rye fiber. Wheat straw is also used for making insulating board. Sound insulators are often also heat insulators. Linofelt, of the Union Fiber Company, Inc., is a sound- and heat-insulating material used for walls. It consists of a quilt of flax fiber between tough waterproof paper. It comes in sheets 5⁄16 to 3⁄4 in. thick.

Torfoleum is a German sound- and heat-insulating material made from peat moss treated with a waterproofing agent. It will withstand temperatures up to 230°F., is finely porous, and weighs less than 1 lb. per bd. ft. Vibration insulators, or Isolators, to reduce vibrations that produce noises, are usually felt or fiber boards placed between the machine base and the foundation. Keldur, of the International Products Corporation, is a fibrous insulating material made up in sheets 3⁄4 in. thick, with a resilient binder. Korfund isolator, of the Korfund Company, Inc., is a resilient mat of cork treated with oil and bound in a steel frame. It will take loadings up to 4,000 lb. per sq. ft.

**Soybean oil.** Also known as Soya bean oil. A pale-yellow oil obtained by expression from the seeds of the plant *Glycine soya*, native to Manchukuo but grown also in the United States. It is used as a substitute for linseed oil for linoleum, paints, and varnishes, or for mixing with linseed oil, although it has only half the drying power of linseed oil. It is also used in core oils and in soaps. The bean contains up to 19 per cent of oil, of which 12 per cent is extracted by expression. The specific gravity of the oil is about 0.925, iodine value 131, and it should have a maximum of not more than 1.5 per cent of free fatty acids and not more than 0.3 per cent of moisture and volatile matter. There are about 280 varieties of the bean listed, and the quality of the oil

varies also with the district and the season. The oil is edible and is used in butter substitutes. Soybean meal is the product obtained by grinding the soybean chips obtained from the expeller process, or the Soybean oil cake obtained from the hydraulic process. The meal is marketed as cattle feed or fertilizer.

**Spanish cedar.** Also called Central American cedar, or in Spanish America, simply Cedro. It is a soft wood from numerous species of *Cedrela*, of a light-red color sometimes beautifully figured with wavy grain. It has an agreeable odor, is easily worked, seasons well, and takes a fine polish. The weight is from 28 to 33 lb. per cu. ft. The tree grows to a large size, logs being available 40 in. square. The imports come chiefly from Central America and the West Indies, but the tree grows as far south as northern Argentina. The wood has a great variety of uses, for cigar boxes, furniture, pattern-making, carving, cabinetwork, and construction. Paraguayan cedar is the wood from the tree *C. braziliensis*, of Paraguay, Brazil, and northern Argentina, employed locally for cabinetwork, car building, and interior building work. It is similar in appearance to Spanish cedar but is denser, harder, and redder in color. See also Mahogany.

**Spanish moss.** The fiber from the plant *Tillandsia usneoides*, which grows throughout tropical and subtropical America, and along the southeastern coast of the United States, hanging from branches of trees. Spanish moss is used for cheap upholstery and for packing glass and fragile articles.

**Speculum metal.** An alloy formerly used for mirrors, and also used in optical instruments. It contains 65 to 67 per cent of copper and the remainder tin. It takes a beautiful polish and is hard and tough. Speculum metal should have a maximum of crystals of $Cu_4Sn$, containing 66.6 per cent of copper. An old Roman mirror contained about 64 per cent copper, 19 of tin, and 17 of lead, and an Egyptian mirror contained 85 per cent of copper, 14 of tin, and 1 of iron. The old Greek mirrors were carefully worked out with 32 per cent of tin and 68 copper. They had 70 per cent of the reflecting power of silver, with a slight red excess of reflection that gave a warm glow, without the blue of

nickel or antimony. This alloy is now plated on metals for reflectors. A modern telescope mirror contains 70 per cent of copper and 30 tin. Chinese speculum contains about 8 per cent of antimony and 10 tin.

**Spelter.** An old name for slab zinc. Metallic zinc was first introduced into Europe from China and was called by the Dutch traders spialter, which was Anglicized to spelter. The first spelter, or metallic zinc, to be produced in the United States was made in 1838 at Washington, D.C. from zincite ore from Franklin, N.J. Sterling spelter is a name applied to a grade of slab zinc. It contains 99.50 per cent of zinc, with a maximum of 0.10 lead and a maximum of 0.03 iron and 0.50 cadmium. See Zinc.

**Spence's metal.** This compound of sulphur with metallic oxides is not a metal. It is prepared by introducing iron disulphide, zinc blende, and galena into melted sulphur. A typical analysis is iron disulphide 57 per cent, sulphur 32 per cent, zinc sulphide 4 per cent, silicic acid, copper sulphate, and other substances, 7 per cent. The color is gray with lustrous dots. It makes clean, full castings, is insoluble in water, and resists well the action of the atmosphere, acids, and alkalies. It is used as a solder for gas pipes, and as a joining material in place of lead. It grips rubber, metals, and stone, and makes a tight joint. The melting point is 320°F., and it expands on cooling.

**Sperm oil.** The fatty oil extracted from the head cavity of the sperm whale, *Physeter macrocephalus*. The spermaceti is first separated out, leaving a clear yellow oil. It is purified by being pressed in bags at a low temperature. It is graded according to the temperature of pressing. A good grade of sperm oil would have a specific gravity of 0.875 to 0.885, and a flash point above 440°F. Inferior grades of sperm oil are likely to be from sperm whale blubber. Commercial sperm oil is likely to be one-third head oil and two-thirds body oil. Sperm oil differs from fish oil and whale oil in consisting chiefly of waxes and not fats. Sperm oil absorbs very little oxygen from the atmosphere and is not influenced by variations in temperature. It is therefore valuable as a lubricating oil, and a fine grade of sperm oil, or Jaw oil, is

used for delicate mechanisms. A good sperm oil from the head has a specific gravity of 0.877, iodine value of 76, and saponification value of 140. See also Whale oil, and Blackfish oil.

Spermaceti is the white, crystalline flakes of fatty substance, or wax, that separate out from sperm oil on cooling after boiling. It differs from ordinary fats in not yielding glycerin when saponified. It is purified by pressing. It is also separated out from dolphin oil. Spermaceti is odorless and tasteless, insoluble in water, but soluble in hot alcohol. It burns with a bright flame. It was formerly used for candles but now is employed as a fine wax.

**Sperrylite.** The only known compound of platinum occurring in nature. It is a rare mineral found in Ontario, Canada, and in Wyoming. Sperrylite is a platinum arsenide, $PtAs_2$, usually found in small grains. It has a hardness of 6 to 7, a specific gravity of 10.6, a tin-white color, and a metallic luster.

**Sphalerite.** Known also as Zinc blende. It is the most important ore of the metal zinc and is found in quantities in Missouri and surrounding states, and in Europe. Sphalerite is a zinc sulphide, ZnS, containing theoretically 67 per cent of zinc. However, iron may replace the zinc to the extent of 18 per cent. It has a massive crystalline or granular structure, and a hardness of about 4. When pure, its color is white; it colors yellow, brown, green, to black with impurities. To obtain the zinc the ore is roasted to reduce the sulphide to an oxide, and then distilled with carbon. The metal is refined by remelting and settling the lead and iron, or by redistilling. The Silesian zinc blende, known as Wurtzite, contains 15 per cent of zinc, 2 lead, and some cadmium.

**Spiegeleisen.** A pig iron, produced in the blast furnace, containing usually from 15 to 30 per cent of manganese, used for making manganese steel by the Bessemer process. The German name, meaning mirror iron, is derived from the fact that the crystals of the fractured face shine like mirrors. The carbon content is from 4.5 to 5.5 per cent. The Electro Metallurgical Company markets two grades, Grade A with 19 to 21 per cent

manganese, and Grade B with 26 to 28 per cent. Both grades have 1 per cent of silicon. Spiegeleisen is now largely replaced by ferromanganese. When spiegeleisen is used for adding manganese to steel, the quantity needed is so great to obtain the required proportion that it must be premelted before adding to the steel. The melting point is from 1950 to 2265°F. Spiegeleisen has an advantage that it can be made directly from low-grade manganese ores. The product made from the New Jersey zinc ores has the added advantage that it is low in sulphur and phosphorus. Spiegeleisen is cheaper than ferromanganese.

**Sponge.** The cellular body of a marine animal, of the genus *Spongia*, of which there are various species. It is employed for wiping and cleaning as it will absorb and hold a great quantity of water in proportion to its weight. Sponges grow like plants, attached to the sea bottom. They are prepared for use by maceration in water, and are then beaten and treated with acids to remove concretions. They may also be bleached chemically. The best sponges come from the Mediterranean and Red Seas, and from the Caribbean Sea. Tarpon Springs, Fla., is the center of the American sponge fisheries. Sponges are sometimes "loaded" with chemicals to increase their weight.

**Sponge iron.** Iron made from ferrous sand and pressed into briquettes, which can be charged directly into steel furnaces instead of pig iron. It was originally made on a large scale in Japan and is economic only where low-grade sandy ores are available. Sponge iron is made by charging the sand continuously into a rotary furnace to drive off the light volatile products and reduce the iron oxide to metallic iron, which is passed through magnetic separators, and the finely divided iron briquetted. Unbriquetted sponge iron, with a specific gravity of 2, is difficult to melt because of the oxidation, but the briquetted material, with a specific gravity of 6, can be melted in the electric furnace.

A form of sponge iron employed as a substitute for lead for coupling packings is made in Germany under the name of Sinterit. The reduction is carried out in a reducing atmosphere at a temperature of 1200 to 1350°C., instead of heating the iron oxide

with carbon. Since the porous iron corrodes easily, it is coated with asphalt for packing use. Iron powder, as produced in Sweden, is made by reducing solid iron ore by the action of carbon monoxide at a temperature below the melting point of the iron and below the reduction point of the other metallic oxides in the ore. It is used for bearings, gears, and other machine parts by compressing and sintering to exact size; the resulting product is porous enough to permit impregnation with oil. Iron sponge, employed as a purifier for removing sulphur and carbonic acid from illuminating gas, is a sesquioxide of iron obtained by heating together iron ore and carbon. It has a spongy texture filled with small cells.

**Sprengle explosives.** Chlorate compounds which have been rendered reasonably safe from violent explosion by separating the chlorate from the combustible matter. The potassium chlorate is made up into porous cartridges and dipped, just before use, in a liquid combustible such as nitrobenzene or dead oil. Potassium chlorate so treated is called Rack-a-rock. Sprengle explosives were formerly used as military explosives, but are very sensible to friction and heat and are now valued only when it is desired to economize on nitrates. Cheddite is a French explosive consisting of a chlorate with an oily material, such as castor oil thickened by having a nitro-hydrocarbon dissolved in it. A typical cheddite has 80 per cent of potassium chlorate, 8 castor oil, and 12 mono-nitro-naphthalene. With sodium chlorate it is less sensitive to detonation and more powerful but is hygroscopic. Potassium chlorate cheddite is a soft, yellowish, fine-grained material, and is a slow, mild explosive which will split rocks rather than shatter them. Minelite is a chlorate with paraffin wax. Steelite is a chlorate explosive with rosin. Prométhée is another French chlorate explosive. In this explosive the oxygen carrier consists of 95 per cent of potassium chlorate and 5 manganese dioxide, and the combustible contains 50 per cent of nitrobenzene, with turpentine and naphtha. It is extremely sensitive and will explode by friction. Silesia is a German high explosive used for blasting. It is potassium chlorate with rosin, with some sodium chlorate to make it less sensitive to detonation.

**Spring brass.** A good quality of sheet brass rolled 8 numbers hard. See Brass. Spring brass has no exact composition but is usually a high brass with from 66 to 72 per cent of copper and the balance zinc, hardened by cold-working. The tensile strength, hard rolled, is about 68,000 lb. per sq. in. and elongation 11 per cent; spring wire may be 100,000 lb. per sq. in. S.A.E. specifications require that such spring brass wire be capable of bending 180 deg. around a wire of its own diameter without cracking. The name Spring bronze is sometimes applied to brass of this kind if it contains some tin. True spring bronze usually contains about 95 per cent of copper, a small amount of phosphorus, and the balance tin. See Phosphor bronze.

**Spring steel.** A term applied to any steel used for making springs. See Spring wire. About 99 per cent of all springs are made of steel, but brass, bronze, nickel silver, and phosphor bronze are used where corrosion resistance or electrical conductivity is desired. Carbon steels, with from 0.50 to 1.0 per cent of carbon, are much used, but vanadium and chrome-vanadium steels are also employed, especially for heavy car and locomotive springs. Special requirements for springs are that the steel be low in sulphur and phosphorus, and the analysis be kept uniform. For flat or spiral springs that are not heat-treated after manufacture, hard-drawn or rolled steels are used. These may be tempered in the mill shape. Music wire is widely employed for making small spiral springs. A much used straight-carbon spring steel has 1 per cent of carbon and 0.30 to 0.40 manganese, but becomes brittle when overstressed. A.S.S.T. carbon steel for flat springs has 0.70 to 0.80 per cent carbon and 0.50 to 0.80 manganese, with a maximum of 0.04 per cent each of sulphur and phosphorus. Motor springs are made of this steel rolled hard to a tensile strength of 250,000 lb. per sq. in. Watch spring steel, for mainsprings, has high carbon, 1.15 per cent, and low manganese, 0.15 to 0.25, rolled hard and giving an elastic limit above 300,000 lb. per sq. in.

Silicon steels are used for springs. They have high strength and impact resistance. These steels average about 0.40 per cent carbon, 0.75 silicon, and 0.95 manganese, with or without

copper, but the silicon may be as high as 2 per cent. Flexo steel, of the Carpenter Steel Company, used for automobile leaf springs and for recoil springs, contains 2 per cent silicon, 0.75 manganese, and 0.60 carbon. The elastic limit is 100,000 to 300,000 lb. per sq. in., depending on the drawing temperature. The hardness is from 250 to 600 Brinell.

Manganese steels for automotive springs contain about 1.25 per cent of manganese and 0.40 carbon, or about 2 per cent of manganese and 0.45 carbon. When heat-treated, the latter has a tensile strength of 200,000 lb. per sq. in. and elongation of 10 per cent. Part of the manganese may be replaced by silicon and the silicon-manganese steels have tensile strengths as high as 270,000 lb. per sq. in. The addition of chromium or other elements increases the elongation and improves the physical properties. Uma spring steel of the Republic Steel Corporation is a chromium-manganese steel with 1 to 1.2 per cent chromium, 0.80 to 1 manganese, and about 0.50 carbon. In the rolled condition it has an ultimate strength of 135,000 lb. per sq. in. and Brinell hardness up to 332. Manganese steels are deep hardening but are sensitive to overheating. The addition of chromium, vanadium, or molybdenum widens the hardening range. Spring wire is marketed in various finishes.

Wire for coil springs ranges in carbon from 0.50 to 1.20, and in sulphur from 0.028 to 0.029. Bessemer wire contains too much sulphur for spring use. Cold-working is the method for hardening the wire and for raising the tensile strength. An 0.85 per cent carbon rod, with an ultimate strength of 140,000 lb. per sq. in., when drawn with 4 or 5 passes through dies will have a strength of 235,000 lb. per sq. in. Wire drawn down to a diameter of 0.015 in. may have an ultimate strength of 400,000 lb. per sq. in. The highest grades of wire are referred to as music wire. See Music wire. The second grade is called Hard-drawn spring wire. The latter is a less expensive basic open-hearth steel with manganese content of 0.80 to 1.10 per cent, and an ultimate strength up to 300,000 lb. per sq. in. Specially treated carbon steels for springs are sold under trade names such as Enduria of the Bethlehem Steel Company. Resilla is a silicon-manganese spring steel of this company.

**Spruce.** The wood of various coniferous trees of northern Europe and North America. Spruce is a leading commercial wood of north Europe and is exported from the Baltic region as White fir, and White deal. It is also called Norway spruce and Spruce fir. The wood is white, and has a straight, even grain. It is tough and elastic, and is more difficult to work than pine. The weight is 36 lb. per cu. ft. Spruce is used for making paper pulp, for packing boxes, and as a general utility lumber. White spruce is from the tree *Picea canadensis*, of the United States and Canada. It has quite similar characteristics. Red spruce, *P. rubra*, is the species found chiefly in the Eastern United States. Silver spruce, Sitka spruce, or Western spruce, is from the enormous tree, *P. sitchensis*, of the Western United States and Canada. It is soft and light in weight, but strong, close-grained, and very free from knots. The weight is less than eastern spruce. The various species of commercial spruce have an average specific gravity, when kiln-dried, of 0.40, a compressive strength of 840 lb. per sq. in. perpendicular to the grain, and a shearing strength of 750 parallel to the grain. It combines stiffness and strength per unit weight. Japanese spruce is from *Abies mariesii*, and Himalayan spruce is from *Picea morinda*. The latter resembles the common spruce of Europe. Sitka spruce is used for the structures of training planes.

**Spruce extract.** A name applied to the waste sulphite liquor from paper pulp mills purified for use in tanning leather. The tanning agent in the liquor is Ligno-sulphonic acid. Spruce extract is not used alone in tanning but is mixed with quebracho or other tanning material, or the leather may first be tanned with spruce and then with syntans. See also Glutrin.

**Stainless iron.** A chromium-iron alloy usually containing from 12 to 20 per cent of chromium, but it may contain as low as 9 per cent. The chromium gives to the alloy the property of being highly resistant to oxidation and corrosion even at elevated temperatures. The resistance to nitric acid increases with the chromium content, and the grades with 16 to 20 per cent of chromium are used for nitric acid equipment. The Brinell hardness is as high as 325, and the tensile strength is up to 150,000 lb. per sq. in. It differs from stainless steel in having low carbon.

Stainless iron is employed for tank plates, and for parts where corrosion- or acid-resisting qualities are valuable, but where the higher strength and hardness of the stainless steels are not required. Stainless iron No. 12 of the Crucible Steel Company of America contains 11 to 13 per cent of chromium, 0.35 to 0.60 manganese, and 0.12 maximum carbon. The tensile strength is 164,000 lb. per sq. in., elongation 11 per cent, and Brinell hardness 321. It forges easily and can be machined readily when annealed. It is used for turbine blades, pump rods, and parts for food machines. Grade No. 18 of the same company contains 17 to 19 per cent of chromium and 0.07 to 0.12 carbon, and has a tensile strength of 100,000 lb. per sq. in., elongation 25 per cent, and Brinell hardness of 200. It is more resistant to acids and corrosion than the No. 12. Uniloy 1409, of the Cyclops Steel Company, has 12 per cent of chromium, 0.50 nickel, and 0.10 carbon. The heat-treated rolled alloy has a tensile strength of 105,000 lb. per sq. in., elongation of 25 per cent, and Brinell hardness of 240. Uniloy 1409M is this alloy with a small amount of molybdenum sulphide to make it free machining.

Turbine blade steel, which is Lesco L of the Latrobe Electric Steel Company, is a stainless iron having 11 to 13 per cent of chromium, 0.50 maximum each of silicon and manganese, and 0.10 maximum carbon. Lesco LM has 13 to 15 per cent chromium and has higher corrosion resistance; Lesco M and Lesco H, with 15 to 18, and 18 to 20 per cent chromium, have still higher resistance. These stainless irons are furnished also with 0.20 to 0.30 per cent of sulphur to give free-machining qualities. Rustless RR-11 of the Rustless Iron and Steel Corporation, is a structural stainless iron containing 11 to 12 per cent chromium and 0.07 carbon. The ultimate strength is 75,000 lb. per sq. in., elongation 25 per cent, Brinell hardness 170, and coefficient of expansion 0.0000125 per deg. C. Stainless iron does not require heat-treatment, but its physical properties are often improved by such treatment, and it can be hardened, although ordinary steel of the same carbon content will not harden.

**Stainless steel.** The trade name of a group of steels containing from 12 to 18 per cent of chromium, originally produced

in America in 1914 under the English Brearley patent, and also under Krupp patents. The patents are now largely held by the Chemical Foundation. Low-chromium steels are not "stainless," the minimum for this purpose being about 12 per cent. However, corrosion-resistant steels with less than 6 per cent of chromium are made containing also tungsten or molybdenum. See Chromium steel and Uniloy chrome steel. The original composition was 13.5 per cent of chromium and 0.35 per cent of carbon. This steel is machinable, has a tensile strength of 150,000 lb. per sq. in., and a Brinell hardness of 325. When quenched in oil from a temperature of 1750°F., this steel has a tensile strength of 240,000 lb. per sq. in. and a Brinell hardness of 500. It can also be hardened by air cooling from a temperature of 1825°F. The steel is also made with a higher carbon content, giving greater hardness, but with increase in carbon the chromium content must also be increased to maintain comparative corrosion resistance.

The original Krupp austenitic, or KA steel, has 20 per cent of chromium and 7 nickel, now usually balanced at 18–8. Radianite, of the Latrobe Electric Steel Company, contains 16.5 to 18 per cent of chromium, 0.70 to 0.80 carbon, and not over 0.50 each of silicon and manganese. It keeps a fine cutting edge, and retains a high polish. Lusterite is another grade with higher carbon, and is a Keen-edge steel for surgical instruments and knives. Low-carbon stainless steel, with only 12.5 per cent of chromium, is used for turbine blades and pump rods. See Stainless iron. The higher carbon content steels up to 0.90 per cent are used chiefly for cutlery and retain a keen cutting edge. Malleable stainless steels are high in chromium but low in carbon. These latter steels do not possess the air-hardening properties of the original stainless steels.

Ordinary stainless steels contain 0.30 to 0.40 per cent of carbon and can be hardened and tempered. Hardness is necessary to bring out the stainless qualities, and the scale must be polished off after tempering. Sterling stainless steel, Type A, of the Firth-Sterling Steel Company, is a typical stainless steel used for automobile parts and for cutlery. It contains 13.5 per cent chromium and 0.35 carbon. The tensile strength is from 100,000 to 240,000 lb. per sq. in., elongation 4 to 27 per cent, specific

gravity 7.77, and Brinell hardness 185 to 500. Steels of this type are also used for making pen nibs to replace gold pens tipped with osmi-iridium. Colonial stainless F.M.S., of the Colonial Steel Company, with a maximum of 0.12 per cent of carbon and up to 0.35 sulphur, is easily machined and is used for valve parts, screws, and gun barrels. A group of stainless steels is produced by the United States Steel Corporation under the name of U.S.S. steels. Duraloy is the name of a group marketed by the Duraloy Company. Defistain, of the Rustless Iron Corporation, is an 18–8 type with low carbon. Enduro 18–8, of the Republic Steel Company, has 0.08 to 0.20 carbon. The tensile strength of this type of steel is 85,000 lb. per sq. in., with elongation of 55 per cent.

Columbium is added to stainless steels of various grades to minimize intergranular corrosion; Columbium stainless steel is used in tank cars. A free-cutting stainless steel is made by adding about 0.40 per cent of zirconium sulphide. The latter makes the steel easy to machine and does not impair the resistance to corrosion, but it decreases the ductility. Carpenter stainless No. 5 contains 14 per cent of chromium, 0.40 of zirconium sulphide, and 0.10 of carbon. Carpenter stainless No. 8 is an 18–9 chromium-nickel steel, with 0.10 carbon and 0.25 selenium. This amount of selenium makes the steel easily machinable. E-Z stainless steel, of the Latrobe Electric Steel Company, is the "regular" stainless steel, with 13.5 per cent chromium and 0.34 carbon, having in addition 0.20 to 0.30 per cent of sulphur to make it easy to machine. Ni-Stainless steel, of the same company, is regular stainless with the addition of 1.5 to 2 per cent of nickel. It gives added abrasion resistance and is used for pump rods, pistons, and valves. Sterling stainless FC, of the Firth-Sterling Steel Company, contains 0.40 per cent molybdenum and 0.25 sulphur, for free-cutting qualities. Circle L25M, of the Lebanon Steel Foundry, is a 21–10 chromium-nickel steel with 0.25 selenium to give free machining. None of the plain chromium steels are "austenitic," but small additions of nickel produce the austenitic condition.

Stainless steels are used in cast and rolled forms for a wide variety of applications where corrosion and acid resistance is important. Super stainless steel is a name given in England by

Hadfield to the 18–8 chromium-nickel steels, but this type is now standard with all makers. See Chromium-nickel steel. A German Chromium-tantalum stainless steel containing 19 per cent of chromium has also 8 per cent of tantalum, 1 per cent silicon, and 0.20 carbon. It is used for special purposes where resistance to scaling at high temperatures is required. Heiloy is the trade name of the Heil Company, for stainless steels used for dairy equipment.

**Starch.** A large group of substances with the empirical formula $(C_6H_{10}O_5)x$ and occurring widely in grains, tubers, and fruits. They are used industrially for pastes, adhesives, fillers, explosives, and stiffening materials. The common cereal grains contain from 55 to 75 per cent of starch. Potatoes have about 18 per cent of starch and 78 per cent of water. Most of the commercial starch is made from corn. The starches from different plants have similar chemical reactions, but all have different granular structure. In general starch is a white, amorphous powder having a specific gravity from 0.499 to 0.513. It is insoluble in cold water. When boiled with water, starch produces a paste and is often used in cooking. Soluble starch is made by allowing starch to stand in contact with cold, dilute acid for some days. Dextrin is a starch with a smaller value of x in the molecule, and is made by heating starch in a dry condition. Starch gives a blue color with iodine, and the dextrins give violet and red. Dextrins have a sweet taste. Dextrin has adhesive properties and is used on envelope flaps and postage stamps. Animal starch, or glycogen, is the reserve food of animals, stored in the muscles and internal organs. Green fruits, especially bananas, often contain much starch until the ripening process has changed the starch to sugar. Potato starch, produced from the common white potato, *Solanum tuberosum*, is the most important commercial starch in Europe. Starch acetates are used as textile sizing and to replace dextrine in adhesives, and also for grease-proofing paper.

**Statuary bronze.** Copper alloys used for casting statues, plaques, and ornamental objects that require fine detail and a smooth, reddish surface. Most of the famous large bronze statues

of Europe contain from 87 to 90 per cent of copper, with varying amounts of tin, zinc, and lead. A general average bronze will contain 90 per cent of copper, 6 tin, 3 zinc, and 1 lead. Statuary bronze for cast plaques used in building construction contains 86 per cent copper, 2 tin, 2 lead, 8 zinc, and 2 nickel. The nickel improves fluidity and hardens and strengthens the alloy, and the lead promotes an oxidized finish on exposure. The statuary bronze used by the Pennsylvania Railroad for passenger car trim averages 83.5 per cent of copper, 4 lead, 2 tin, and 10 zinc.

**Stearic acid.** A hard, white, waxlike substance used for making paint driers, soaps, and waterproofing compounds. It is the common constituent of hard fats, and is a white mass of the composition $CH_3(CH_2)_{16}COOH$, soluble in alcohol but insoluble in water. The specific gravity is 9.842, melting point 69°C. and boiling point 291°C. It is obtained from fats and oils by "splitting" and distilling, or it can be made from oleic acid by hydrogenation. Stearic acid is also used for making candles, usually mixed with palmitic acid or paraffin. Oleo stearin, used for filling and finishing leather, is the stearin remaining after extraction of the edible Oleo oil from cattle fats. Stearite is a trade name for Synthetic stearic acid made by the hydrogenation of unsaturated animal and fish oils. It is used in rubber compounding as it is more uniform than natural stearic acid.

**Steel.** A chemical compound of iron and carbon, with no carbon in the free state. Its strength is greater than iron. When raised to a red heat and cooled suddenly, it becomes exceedingly hard. This hardness can be modified by subsequent heating and cooling. The average weight is 0.283 lb. per cu. in. and coefficient of expansion 0.0000066. The melting point varies with the carbon, but is always higher than that of cast iron with the same combined carbon. Steel is graded according to the percentage of carbon in it, the highest grades having the most carbon. The usual proportions of carbon vary from 0.15 to 1.5 per cent. Steel containing less than 0.15 per cent of carbon hardens only slightly; that with more than 1.25 per cent becomes brittle. The low-carbon steels machine easily and can be forged readily; those containing about 1 per cent of carbon are difficult to forge and

machine. All steels contain some manganese, usually above 0.30 per cent, left after deoxidizing and desulphurizing with ferromanganese. The latter forms MnS and MnO with residual sulphur and oxygen, which passes off in the slag, freeing the steel of the original embrittling FeS and FeO compounds.

Steel is roughly divided into four groups: Low-carbon steel, with 0.15 to 0.30 per cent of carbon; Medium-carbon steel, with 0.30 to 0.60 carbon; High-carbon steel, with 0.60 to 0.90 carbon; and Very high-carbon steel, with 0.90 to 1.5 per cent of carbon. Mild steel is a shop term for low-carbon steel. See Ingot iron. Low and medium steels are used in construction, and high-carbon steels for tools. Sulphur makes steel hot short, or brittle, at red heat, but it aids machinability. See Screw stock. Dirty steel is steel with inclusions of iron oxide from scrap used in the converter. Various trade names are applied to particular steels or to designate groups of steels of a particular company. Carilloy is a name given by the Carnegie-Illinois Steel Corporation to all of its alloy steels. Dixisteel is the trade name of the Atlantic Steel Company for its structural steels. Crestoloy is the trade name of the Crescent Tool Company for strong alloy steel used for its tools. Ryolite steel is the trade name of Joseph T. Ryerson & Son, Inc., for alloy, tool, and structural steels.

Rolled or forged steel is stronger, tougher, and more ductile than cast steel. Electric steel is made in either the induction or the arc-type electric furnace, and is of uniform quality and of higher strength and ductility than open-hearth steel of the same carbon content. Crucible steel is made by melting wrought iron with charcoal and cast iron. Bessemer steel is made by decarbonizing cast iron by forcing a powerful blast of air through the molten iron. Open-hearth steel is made by fusing cast iron with wrought iron, or with steel scrap, in a regenerative furnace. Cementation consists in heating bars of wrought iron in contact with carbon. The product is known as Blister steel.

The tensile strength of typical open-hearth steel varies from about 50,000 lb. per sq. in. for a 0.12 carbon steel to 110,000 lb. for a 0.55 carbon steel, with elongations of 29 and 12 per cent, respectively. The ordinary Wrought steel used by the Republic Steel Corporation for wrought steel pipe has a tensile strength

of 52,000 to 62,000 lb. per sq. in., minimum yield point of 30,000 lb. per sq. in., and minimum elongation of 20 per cent. Steels containing less than 0.15 per cent of carbon, which are technically classed as irons, are used for wire, nails, rivets, and screw-machine products. Ordinary forgings are made from steel of 0.15 to 0.30 carbon, and strong forgings from steel with 0.35 to 0.40 carbon, but most strong forgings are now made of alloy steels. Raising the carbon content from 0.40 to 0.45 per cent will increase the possible hardness of the steel about 10 per cent. Water quenching of steels gives the greatest hardness in carbon steels, but the rapidity of cooling often causes cracking, so that very high-carbon steels or small thin parts made in lower carbon steels are quenched in oil. See also Nickel steel, Silicon steel. A Structural copper steel, "Man-Ten," of the U.S. Steel Corporation, is a medium-carbon, medium-manganese high-strength steel.

**Steel powder.** Finely divided steel powder used for molding under hydraulic pressure into various parts which are then sintered at a temperature of 1075°C. The tensile strength of the molded and sintered products is about the same as that of cast steel of the same composition. It has the advantage that there is no metal loss in machining, and accurate gears, cams, and other parts can be made without machining labor. Sinterloy is the name of a steel powder marketed by Charles Hardy, Inc., in compositions of 0.05, 0.40, and 0.80 carbon. Some grades also contain nickel and chromium. See also Iron-powder.

**Steel wool.** Long, fine fibers of steel used for abrasive purposes, chiefly for cleaning utensils and for polishing. It is made from low-carbon Bessemer wire of high-tensile strength, usually having 0.10 to 0.20 per cent of carbon and 0.50 to 1.00 per cent of manganese. The wire is drawn over a track and shaved by a stationary knife bearing down on it. A special machine also is made for shaving off the wool in a continuous piece and winding it around wheels. Fibers of a length of 100,000 ft. have been made. Steel wool usually has three edges but may have four or five, and strands of various types are found together. There are nine standard grades of steel wool, the finest of which has no fibers greater than 0.0005 in. thick, the most commonly used

grade having fibers that vary between 0.002 and 0.004 in. The medium grades resemble wool in texture.

**Stephanite.** An ore of silver. It is a sulph-antimonite of silver, $Ag_5SbS_4$, containing 68.5 per cent of silver and 15.2 per cent of antimony. It is found associated with other ores of silver in Nevada and in Mexico, Peru, Chile, Saxony, Bohemia, and Hungary. Its hardness is 2 to 2.5 and specific gravity 6.2 to 6.3. It occurs massive or in grains, of an iron black color.

**Sterling silver.** Since silver is a very soft metal, it is not used industrially in its pure state, but is alloyed with a hardener, usually copper. Sterling silver is the name given to a standard high-grade alloy containing a minimum of 925 parts in 1,000 of silver. It is used for the best tableware and for jewelry. Sterling silver is made by melting the silver and copper together in a crucible using a cover of charcoal to prevent spitting. The 7.5 per cent of copper makes the alloy so hard that it requires annealing between rollings. See Silver. Silver may sometimes be hardened with other elements besides copper. Silanca is a silver hardened with small amounts of zinc and antimony, but the name sterling is applied only to the Silver-copper alloy.

**Stibnite.** The chief ore of the metal antimony. It is Antimony trisulphide, $Sb_2S_3$, containing 71.4 per cent of antimony, with sometimes gold or silver. It occurs in slender prismatic crystals of a metallic luster and lead-gray color. It has a hardness of 2. The antimony is obtained by melting stibnite with iron, forming FeS and liberating the antimony, by roasting the ore to produce $Sb_2O_4$ and then reducing with carbon. Stibnite comes from China, Japan, Germany, Mexico, and New South Wales, with a little in the Western United States. For pyrotechnic uses stibnite is "liquated" by melting the mineral and drawing off the liquid. On cooling it solidifies and is then ground.

**Stillingia oil.** A drying oil obtained from the kernels of the seeds of the tree *Stillingia sebifera*, cultivated in China. The seeds contain about 23 per cent of a light yellow oil resembling linseed oil but of somewhat inferior drying power. The oil has a specific gravity of 0.943 to 0.946 and iodine value of 160. It has the

peculiar property of expanding with great force at the congealing point. Stillingia oil is edible, but deteriorates rapidly, becoming bitter in taste and disagreeable in odor. Stillingia tallow, also known as Chinese vegetable tallow, is obtained by pressing from the coating, or mesocarp, of the seeds. Sometimes the whole seed is crushed, producing a softer fat than the true tallow. The tallow contains palmitic and oleic acids and is used in soaps and for mixing with other waxes.

**Stockenette.** A heavily napped knitted cotton fabric, used for covering inking or oiling rolls in machinery and for covering cured meats. It is knitted in seamless tubes or as a flat fabric.

**Strontium.** A metallic element of the alkaline earth group, symbol Sr. It occurs in the minerals Strontianite, $SrCO_3$ and Celestite, $SrSO_4$, and resembles barium in its properties and combinations. It has a pale-yellow color, specific gravity of 2.54, melting point about 900°C., and it decomposes water. It is obtained only with difficulty in its metallic state, but strontium compounds are used as deoxidizers in nonferrous alloys, and in fireworks to furnish oxygen and give a colored flame. Strontianite is used in Germany as a desulphurizer for steel.

**Strontium nitrate.** A yellowish-white, crystalline powder of the composition $Sr(NO_3)_2$. It is the strontium salt of nitric acid and is prepared by roasting Celestite, leaching out the strontium sulphide and dissolving the strontium carbonate in dilute nitric acid. The yellowish commercial product is 99.5 per cent pure. It is soluble in water but insoluble in alcohol. The specific gravity is 2.96 and melting point is 645°C. Strontium nitrate gives a beautiful crimson flame and is used in red lights, railway-signal flares, and signal stars. It also furnishes the oxygen necessary for the combustion of the compounds. A typical flare compound contains 50 per cent of strontium nitrate, 37½ of potassium chlorate, and 12½ of shellac, the last serving as a binder and to furnish heat of combustion.

**Suède.** Also called Napped leather. A soft-finished, chrome-tanned leather made from calf, kid, or cowhide splits. It is worked on a staking machine until it is soft and supple, and then

buffed or polished on an abrasive wheel. It has a soft nap on the polished side and may be dyed in any color. Suède is used for shoe uppers, coats, hats, and pocketbooks. Artificial suède, with the general trade name of Izarine, has a base of rubberized fabric. A thin coating of rubber cement is applied to one side which is sprinkled with fine cotton fibers dyed in colors. The sheet is beaten from the bottom to make the fibers stand out until the cement hardens. It is then vulcanized. The fabric looks and feels like fine suède.

**Sugar pine.** The common name of the wood of the *Pinus lambertiana*, a coniferous tree growing in California and Oregon. The tree grows ordinarily to a height from 150 to 175 ft. with a diameter of 4 to 5 ft. Occasional trees are more than 200 ft. in height and 12 ft. in diameter. The stand is estimated to be 35 billion bd. ft. and is cut at the rate of 300 million ft. annually. Sugar pine is durable, has moderate strength, fairly even grain, and is not subject to excessive shrinkage or warping. Because of the latter quality it has come into use to replace the scarcer eastern pines for patterns. It is widely employed for construction work and for "Factory lumber" for doors, frames, boxes, and wooden articles. Sugar pine is classified into three standard classes of grades according to freedom from knots and faults as: Select, Commons, and Factory, or Shop. The selects are designated as No. 1, and 2 clear, C select, and D select. The commons are graded as No. 1, 2, 3, and 4, and the factory as No. 3 clear, No. 1 shop, No. 2 shop, and No. 3 shop. The "shops" are judged with the idea that they will be cut up into small pieces, and are consequently classified by the area of clear cuttings that can be obtained.

**Sulphonated oil.** A fatty oil that has been treated with sulphuric acid, the excess acid being washed out, and only the chemically combined acid remaining. The oil is then neutralized with an alkali. Sulphonated oils are "soluble" and are used in cutting oils and in fat liquors for leather finishing. Sulphonated castor oil is called Turkey red oil. Leatherlubric is the trade name of E. F. Houghton & Company for sulphonated sperm oil used for leather. Solcod is the sulphonated cod oil

of the same company. Sulphonated stearin and Sulphonated tallow are also used in leather dressing. They are cream-colored pastes readily soluble in hot water. See Fat liquors.

**Sulphur.** An element which occurs abundantly in its uncombined state. Its symbol is S. It is obtained from the gypsum deposits of Texas and Louisiana, and from volcanic deposits in Sicily, Mexico, Chile, and Argentina. It is purified by distillation. It can also be obtained by distillation from iron pyrites and as a by-product from copper and zinc smelting. Sulphur forms a crystalline mass of a pale yellow color. Its hardness is 1.5 to 2.5 and specific gravity 2.05 to 2.09. It melts at 232°F. At about 780°F. it is converted into a ruby-colored vapor. Sulphur also condenses in light flakes, in which form it is known as Flowers of sulphur. The amorphous sulphur has a specific gravity of 1.955. When melted and cast into sticks, it is known as Brimstone. Sulphur has a great affinity for most metals and combines with great energy when heated together with them. Sulphur, even in very small quantities, makes metal alloys brittle and must ordinarily be kept out of commercial metals. Sulphur has many uses in the formation of sulphur compounds and sulphuric acid, for making gunpowder, for vulcanizing rubber, for bleaching cloth, as a fumigant, and in medicine. It is also used as a cement for anchoring iron in stone and for lining iron pipes for brine waters. Commercial crude Sicilian sulphur contains from 2 to 11 per cent of impurities and is sold in three grades. Refined sulphur is marketed in crystals, roll, or various grades of powder, and the Sicilian "superior" grade is 99.5 per cent pure. This is the grade used in rubber manufacture.

Vegetable sulphur is not sulphur, but the name is a colloquial term for Lycopodeum, also known as Club moss. It is a fine yellow powder derived from the spores of a fernlike plant growing in North America, Europe, and Asia. Its chief use is in medicine, but it is also employed in fireworks and flashlight powder and as a dusting powder for sand molds for fine castings.

**Sulphur dioxide.** Also known as Sulphurous acid anhydride. It is colorless gas of the composition $SO_2$, employed for industrial

bleaching, as a preservative, and in refrigeration. It is used extensively for domestic refrigerating machines. The gas is poisonous, but has a pungent, suffocating odor and is thus detected easily. It is also easy to locate small leaks by cloud test with ammonia. It is corrosive to organic materials but does not attack copper or brass. Sulphur dioxide in refrigerating machines has a condensing pressure of 51.7 lb. gage at 86°F., and a pressure of vaporization of 2.9 lb. gage at 5°F. It boils at −10°C. It is soluble in water, forming Sulphurous acid. Sulphur dioxide is produced by roasting pyrites in a furnace. Sulphurous acid is a colorless liquid of the composition $H_2SO_3$, with suffocating fumes. It is made commercially by absorbing the sulphur dioxide gas in water. The U.S.P. grade has a strength of 6 per cent. Sulphurous acid is used in industrial bleaching.

**Sulphuric acid.** Also called Oil of vitriol. An oily, highly corrosive liquid of the composition $H_2SO_4$, used for pickling and cleaning metals, for plating baths, for making explosives, for electric batteries, and for many other purposes. In weak solutions sulphuric acid is sometimes known in the metal industries as Dipping acid, and in the automotive trade as Battery acid. Concentrated acid, or Fuming sulphuric acid, was known as Nordhauser acid. The specific gravity is 1.834 and boiling point 210°C. It is miscible in water in all proportions. The color is yellowish to brownish according to the purity. It disintegrates wood, rubber, and most organic materials and many metals, but the weak acid does not dissolve lead or mercury. Sulphuric acid is made by various processes from pyrites, or by oxidizing the sulphur dioxide from the waste gases of copper and zinc smelters and absorbing the gas in water. In Germany it is made from gypsum by breaking down and treating the $SO_2$ gas. The common commercial grade of sulphuric acid known as oil of vitriol is 66° Bé., which is 93.2 per cent acid. Other grades are 50 and 60° Bé.

Niter cake, which is Sodium acid sulphate, $NaHSO_4$, or Sodium bisulphate, contains 30 to 35 per cent of available sulphuric acid and is used in hot solutions for pickling and

cleaning metal articles. It comes in colorless crystals or white lumps, of a specific gravity of 2.435 and melting point of 300°C. Salt cake, $NaSO_4$, is impure Sodium sulphate used in the cooking liquor in making paper pulp from wood. In the process it is changed to Sodium sulphide, $Na_2S$, and "digests" the material. It is also used in freezing mixtures. The Sodium sulphide used as a de-hairing agent in tanneries, comes as a 20 per cent liquid, or as crystal or flake. Kaiseroda is a German name for salt cake of high purity produced by treating magnesium sulphate, obtained from refining potash with common salt to produce salt cake and magnesium chloride. It contains 98.3 per cent sodium sulphate.

**Sunn hemp.** The fiber of the plant *Crotalaria juncea.* It is used for cordage and rope in place of jute, but is lighter in color and is more flexible and stronger than jute. It resembles true hemp. The plant, which is a shrub, is cultivated extensively in India. It grows to a height of about 8 ft., with slender branches yielding the fiber. The method of extraction is the same as for true hemp. The best fibers are retained locally for making into cloth. Sunn hemp is also called Indian hemp; Madras hemp is from another species of the same plant. Sunnee, also called Brown Indian hemp, is a fiber from the plant, *Hibiscus cannabinus*, of India. It is used as a substitute for hemp.

**Superbronze.** A name applied to brasses containing both aluminum and manganese. They are ordinarily high brasses modified with 2 to 3 per cent of manganese and 1 to 6 per cent of aluminum, with sometimes also some iron. They have greatly increased strength and hardness over the original brasses, but the ductility is reduced and they are difficult to work and machine. The early superbronze was known as Heusler alloy. Muntz metal is also frequently modified with manganese, iron, and aluminum. See Muntz metal. The alloys are used where high strength and corrosion resistance are required, and they are often marketed under trade names. Tensilite, of the American Manganese Bronze Company, is a bronze of this type. A grade containing about 64 per cent of copper, 30 zinc, 2.5 manganese, 3 aluminum, and 1 iron, has a tensile strength, cast, up to

100,000 lb. per sq. in. and elongation of 16 per cent. Mallory metal is a superbronze of the P. R. Mallory Company. See also Manganese bronze.

**Sycamore.** The wood of the tree *Acer pseudo-platanus*, which is also classed as a kind of maple, especially in England. The species cut as sycamore in the United States is *Platanus occidentalis*. The wood has a close, firm, tough texture and is yellowish in color. The weight is about 38 lb. per cu. ft. The surface is lustrous and takes a fine polish. It is used for veneers, flooring, furniture, and for handles and rollers.

**Synthetic resins.** A large group of resinlike materials, more properly called Resinoids, produced synthetically by either the condensation or polymerization of various chemicals. They are employed for molding mechanical, electrical, or ornamental articles, or are used in solution in lacquers, varnishes, enamels, adhesives, and coatings. Molding plastics, in general, are of four types: Synthetic resins; natural resins, including rubber and bitumens; cellulose derivatives; and proteins such as casein or soybean hardened with chemicals. The synthetic resins, in general, set to hard materials that are not thermoplastic like the cellulose materials. The chief groups of synthetic resins are Phenolaldehyde, Amino-aldehyde, Hydroxy-carboxylic or alkyl, vinyl, acrylic, styrene, and indene. The first three are condensation resins, and the others are polymerization resins. See Phenolformaldehyde resins, Acrylic resins, Indene resins. The synthetic resins are usually marketed in powder or other form in which the chemical action has been stopped, and the final stage is done by heat and pressure in the forming molds. Before molding they are usually mixed with fillers and pigments to give various characteristics. For use in adhesives and lacquers they may be mixed with plasticizers and other resins or gums to give flexibility or other characteristics. The German patented resins, known as Albertol resins, are composed of synthetic resins combined with natural resins to give pliancy in the molded article. Synthetic resins are marketed under many trade names such as Durium, Uformite, Insurox. The English acrylic resin Perspex is used for aircraft sheeting.

**Talc.** A soft, friable mineral, usually oily and yielding to the touch. The very white colloidal talc, such as that from the Alpine cliffs of northern Italy, with a soapy feel, is used for cosmetics; the massive form is employed as a filler for paper, paints and rubber, in cookers and heaters as a heat insulator, and in ceramic mixtures for whiteware and for electrical porcelain. Talc is a hydrated magnesium silicate of the theoretic composition $4SiO_2 \cdot 3MgO \cdot H_2O$, occurring in white, gray, green, brown, or red colors, with a hardness of 1 and a specific gravity of 2.8. The gritty varieties contain carbonate minerals. The lime-free talcs are desired for electric heater plates where minimum thermal expansion and resistance to heat shock are needed; lime talcs are preferred for porcelains. It is known as Asbestine and other trade names when used as a filler. Asbestine, of C. K. Williams & Company, is a talc powder of 325 mesh. French chalk is a high-grade talc in massive block form used for marking. Talc is a secondary mineral formed from magnesium silicates. See also Soapstone. The mineral occurs in the United States in the Appalachian region from Vermont to Georgia. Agalite is a mineral having the same composition as talc but with a less soapy feel. It is used as a filler in cheap writing papers, but is more wearing on the paper rolls than talc. The talc of northern New York, known as Rensselaerite, does not have the usual talc "slip" and has a fibrous nature. The hydrous aluminum silicate Pyrophyllite, found in California, is similar to talc but with the magnesium replaced by aluminum. In mixtures with talc for wall tile it eliminates "crazing." It is also substituted for talc as a filler for paints and paper.

**Tallow.** A general name for the heavy fats obtained from all parts of the bodies of sheep and cattle. The best grades of internal fats, or Suet, are used for edible purposes, but the external fats are employed for lubricants, for mixing with waxes and vegetable fats, for soaps and candles, and for treating leather. About half of the fatty materials used in the United States for soaps are grades of tallow. The tallows consist largely of stearic, palmitic, and oleic acids. The edible grades known as Premier jus, Prime, and Edible, are white to pale yellow,

almost tasteless, and free from disagreeable odor, but the nonedible or industrial tallows are yellow to brown unless bleached. The best grade of industrial tallow is Packers No. 1.

**Tanning agents.** Materials, known as Tannins, used for the treatment of skins and hides to preserve the hide substance and make it resistant to decay. The tanned leather is then treated with fats or greases to make it soft and pliable. Tannins may be natural or artificial. The natural tannins are chiefly vegetable, but some mineral tanning agents are used. The vegetable tannins are divided into two color classes, the Catechol and the Pyrogallol. The catechol tannins are Cutch, quebracho, hemlock, larch, gambier, oak, and willow. The pyrogallol tannins are Gallnuts, sumac, myrobalans, chestnut, valonia, divi-divi, and algorobilla. Catechol tannin is distinguished by giving a greenish-black precipitate with ferric salts; the pyrogallol tannins give a bluish-black precipitate. The catechol tannins, in general, produce leathers that are more resistant to heat and decay than the pyrogallols. Some tannins contain considerable coloring or dye matter, but the color that a tannin imparts to leather may be lightened or darkened by raising or lowering the acidity of the tanning bath.

Alum tanning is an ancient process but was introduced into Europe only about the year 1100, and the alum and salt tanned leather was called Hungary leather. Formaldehyde is also used as a tanning agent. See Chamois. Formaldehyde was patented as a tanning agent in 1898. A later patent covered a rapid process of tanning sheepskins with alcohol and formalin and then neutralizing in a solution of soda ash. Unlike vegetable agents, formaldehyde does not add weight to the skin. It is often used as a pre-tanning agent to lessen the astringency of the vegetable tannin and increase its rate of diffusion. Leather may also be tanned with chromic acid or chrome salts, which make the fibers insoluble and produce a soft, strong leather. Chrome alum, sodium or potassium dichromates, or products in which chromic acid has been used as an oxidizing agent may be used. Chrome tanning is rapid and is used chiefly for light leathers. Tanolin is a name for basic Chromium chloride mar-

keted in crystal form for use in the chrome tanning of leather. Santotan KR is a trade name of the Monsanto Chemical Company for basic Chromium sulphate, $Cr_2(SO_4)_2(OH)_2$, used as a one-bath chrome tanning agent. Panchrome is the trade name of an English tanning agent which is a sulphur dioxide dichromate. Chromalin is a glycerin-reduced dichromate. Chrome-tanned leather is more resistant to heat than vegetable-tanned leathers, withstanding temperatures to 200°F. Chrome tanning is used for shoe upper leathers and for gloves, belting, and packings. In tanning processes various supplementary materials may be used to give special properties to the leathers. Glucose or starch may be used to make the leather more plump. Hydrochloric acid is used in two-bath chrome tanning to enhance the feel and appearance of the leather. See Fat liquors. Synthetic tannins, or Syntans, are largely condensation products made by condensing sulphonic acid with formaldehyde. Neradol D is such a syntan. Tansyn is the trade name of an English syntan of this kind. Syntans do not add weight to leather and are seldom used alone. They are marketed under trade names. Leukanol, of the Rohm & Haas Company, has a bleaching action and is used in combination with vegetable tannins to speed up the tanning and to give a light-colored leather.

**Tantalite.** The most important ore of the metal tantalum. When pure, its composition is $FeO \cdot Ta_2O_5$, but the American ore may contain only from 10 to 40 per cent of Tantalic oxide, $Ta_2O_5$, and the Australian ore may contain as high as 70 per cent. The ore is marketed on the basis of 60 per cent tantalic oxide content. Tantalite occurs usually as a black crystalline mineral with a specific gravity up to 7.3. It often contains manganese, tin, titanium, and sometimes tungsten; the tantalum may be replaced by columbium, which is similar to it. When the columbium content in the ore predominates, the mineral is called Columbite. Tantalite also contains small amounts of germanium. Tantalum metal is produced from tantalite by dissolving in acid and separating the tantalum salts from the columbium by precipitation. The tantalum salts are reduced to powdered metal, which is then compressed into rods and

sintered and rolled. One pound of tantalum is produced from about 2½ tons of American ore. Australia is the most important source of tantalite.

**Tantalum.** A white, lustrous metal resembling platinum. It is one of the most acid resistant of the metals and is classed as a noble metal. The specific gravity is 16.6, or about twice that of steel, and the melting point is very high, 2850°C. It is very ductile and can be rolled down from 0.300 to 0.0015 without annealing, or drawn into extremely fine wire. The tensile strength of the sheet metal is 50,000 lb. per sq. in., and of the drawn wire 130,000 lb. per sq. in. The annealed metal has a hardness of 75 Brinell. It is resistant to all acids except hydrofluoric, and is not dissolved by aqua regia. It will dissolve, however, in a mixture of nitric and hydrofluoric acids, and also reacts with chlorine above 175°C. When heated in the air to about 400°C. it becomes blue; at a higher temperature, it becomes black. At very high temperatures it absorbs oxygen, hydrogen, or nitrogen, and becomes very brittle. It will absorb 740 times its own volume of hydrogen, producing a coarse, brittle substance. Tantalum can be tempered or hardened to about 600 Brinell by heating in the air to absorb gases, and will hold a fine cutting edge on tools. It can also be hardened by the addition of silicon to a hardness close to that of the diamond, but any alloying of tantalum is difficult because of the high melting point.

Tantalum is used as a filament in electric light bulbs. The metal becomes incandescent at 1700°C., or 400° below that of tungsten, so that a tantalum lamp is cooler. It is also used in radio tubes, and in vacuum tubes to absorb gases. It is lower in cost than platinum, and is used for surgical instruments, pens, instruments, and acid-resistant chemical equipment. Tantalum coils are used to heat acid baths. A tube with a wall thickness of 0.020 in. will withstand operating steam pressure up to 150 lb. per sq. in. The metal has the property of passing an alternating electric current in one direction only, and is thus used for current rectifiers. As an anode tantalum reacts instantly with oxygen in acid solutions forming a stable oxide film which

is current-blocking; this property is used in rectifiers and electrolytic condensers. See Rextox.

**Tantalum carbide.** An extremely hard, heavy, brownish crystalline material of high melting point, 3875°C., used for the same purposes as tungsten carbide, as an abrasive and cutting material. It has the composition TaC, and in hardness it ranks close to the diamond. For use in cutting tools the carbide is ground to 325 mesh, mixed with a binder of powdered cobalt, iron, or nickel, molded to shape, and sintered at high heat. Ramet is the trade name of the Fansteel Metallurgical Corporation for tantalum-carbide cutting materials, and Tantaloy is a name for a sintered alloy in bar form for flowing on faces of tools with a welding torch. Vascoloy-Ramet is a name given by the Vascoloy-Ramet Corporation to tantalum-carbide cutting and wear-resistant materials in various grades. They have a hardness range from Rockwell A 88.4 to 92.5.

**Tar.** A black solid mass obtained in the distillation of coal. When coal is heated to redness in an enclosed oven, it yields volatile products and the residue coke. Upon cooling the volatile matter, tar and water are deposited, leaving the coal gases free. Various types of coal yield tars of different qualities and quantities. Anthracite gives little tar, and cannel coal yields large quantities of low-gravity tar. In the manufacture of gas the tar produced is a viscous black liquid containing 20 to 30 per cent of free carbon, and is rich in benzene, toluene, naphthalene, and other aromatic compounds. In the dry state this tar has a specific gravity of about 1.20. Tar is also produced from coke ovens and as a by-product of blast furnaces using coal as a fuel.

Coal tars are usually distilled to obtain the aromatic substances, and the residue tar, known as Treated tar, or Pitch, is used for making roofing, for road making, and for bituminous paints and waterproofing compounds. Coal-tar pitch is the most stable bituminous material for covering underground pipes. Crysolite paint, of the Semet-Solvay Company, is a corrosion-resistant and acid-resistant paint with a base of refined coke-oven pitch, which is mixed with vegetable drying oils. The color

is black. It is used for painting tanks, smokestacks, and structural steel. The lightest distillate of coal tar, benzol, is used as an automotive fuel and gives greater mileage than gasoline. Naphthalene and anthracene are among the distillates. Tar is also obtained as a by-product in the destructive distillation of pitch-pine wood. Pine tar is a black viscous mass, used for roofing. It is also sometimes called pitch. Wood tar from the destructive distillation of other woods is a dark-brown viscous liquid used as a preservative, deriving this property from its content of creosote. Tarvia is the trade name of a refined coal tar, marketed by the Barrett Company in various grades. Tarmac is practically the same material marketed by the Koppers Co., Tar & Chemical Div. Bituvia is a road tar, produced in various grades by the Reilly Tar and Chemical Corporation.

**Taylor process wire.** Very fine wire made by the process of drawing in a glass tube. The process is used chiefly for obtaining fine wire from a material lacking ductility, such as antimony, or extremely fine wire from a ductile metal. The procedure is to melt the metal or alloy into a glass or quartz tube, and then draw down this tube with its contained material. Wire as fine as 0.00004 in. in diameter is made commercially by this process. Wires of this kind can be obtained only in short lengths but, since they are used only for electrical instrument and laboratory work, this is not ordinarily an objection.

**Teak.** The wood of the tree *Tectona grandis*, of southern Asia. It is shipped from Burma in very large logs. It resembles oak in appearance, is strong and firm, and in England is called Indian oak. It contains an essential oil which gives it a pleasant odor and makes it immune to the attacks of ants and other insects. It is used for boxes, chests, and in boat building. The color is golden yellow, the grain is coarse and open, and the surface is somewhat greasy to the touch. The weight is about 45 lb. per cu. ft. In Burma large plantations grow teak for export. The wood marketed as African teak, known also as Iroko, is from the tree *Chlorophora excelsa*, of West Africa, and is unlike true teak. It is a firm wood with a brownish color and a coarse, open grain. The weight is somewhat less than teak.

**Tear gases.** An important group of lachrymatory poisons used in chemical warfare. They have a powerful irritating effect on the eyes, producing temporary blindness by a continuous flow of tears and swelling of the eyes. The chief advantage is that only small quantities are required, one part in 10 million parts of air being sufficient to disable a man. One lachrymatory shell can have the same disabling effect as 500 phosgene shells, although the effect is usually only temporary. Most of the tear gases, except acrolein, are also poisonous, having after effects, and such gases as chloropicrin are highly lethal. Acrolein, one of the original tear gases, is Acrylic aldehyde, $CH_2:CH\cdot CHO$, made by heating glycerol with a dehydrating agent. It is a volatile liquid, boiling at 52°C., and is extremely irritating to the eyes and nose. The unpleasant effect of scorching fat is due to acrolein. Bromoacetone is a colorless liquid of the composition $CH_2BrCOCH_3$, with a specific gravity of 1.631 and boiling point 126°C. It is thrown in high-explosive shells and disseminated as a mist. Bromoacetone attacks the eyes, causing a copious flow of tears. Bromobenzyl cyanide is another chemical used in high-explosive shells. It is a solid of the composition $BrC_6H_4\cdot CH_2CN$, having a melting point of 25°C.; when impure it is a liquid, and is not purified since it is easily decomposed. It is very persistent and has a sour, irritating odor, being classed as a Harassing agent. Another tear gas, Chloroacetophenone, $C_6H_5COCH_2Cl$, is a white, crystalline solid, specific gravity 1.321 and melting point 59°C., which, when thrown as a vapor, has a sweet, locustlike odor but produces pains in the eyes and temporary blindness. Other tear gases include chloropicrin, benzyl chloride, benzyl bromide, cyanogen chloride, martonite, xylyl bromide. The French gas Fraissite is Benzyl iodide, $C_6H_5CH_2I$, a liquid boiling at 226°C. The gas Papite is acrolein with stannic chloride. Caderite is benzyl bromide with stannic chloride.

**Tellurium.** An elementary metal, symbol Te, obtained as a steel-gray powder of 99 per cent purity by the reduction of Tellurium oxide recovered from the residues of lead and copper refineries. It is also marketed in slabs and sticks. It occurs also

with gold in Washington and Colorado as Gold telluride, $AuTe_2$. The specific gravity is about 6.2 and melting point 450°C. The chief uses are in lead to harden and toughen the metal, and in rubber as an accelerator and toughener. Less than 0.1 per cent of tellurium in lead makes the metal more resistant to corrosion and acids, and gives a finer grain structure and higher endurance limit. Tellurium-lead pipe, with less than 0.1 per cent of tellurium, has a 75 per cent greater resistance to hydraulic pressure than plain lead. A Tellurium lead, patented in England, contains 0.05 per cent of tellurium and 6 antimony. Tellurium copper is a free-machining copper containing about 1.0 per cent of tellurium. It machines 25 per cent easier than free-cutting brass. The tensile strength, annealed, is 30,000 lb. per sq. in., and the electrical conductivity is 98 per cent that of copper. A Tellurium bronze containing 1 per cent of tellurium and 1.5 tin has a tensile strength, annealed, of 40,000 lb. per sq. in., and is free machining. As a secondary vulcanizing agent with sulphur in rubber, tellurium in very small proportions, 0.5 to 1.0 per cent, increases the tensile strength and ageing qualities of the rubber. It is not as strong an accelerator as selenium, but gives greater heat resistance to the rubber. Telloy is the trade name of R. T. Vanderbilt Company for tellurium powder ground very fine for rubber compounding.

**Terne plate.** Bessemer or open-hearth steel plate containing on each side a thin coating of an alloy of 20 per cent tin and 80 lead, although other proportions may also be used. Terne is an old name meaning dull and refers to the color as compared with bright tin plate. Terne plate is made by the dip process and is used for roofing, construction work, and to replace the more expensive tin plate for uses not in contact with foodstuffs. The coating is measured by the pounds per double base box containing approximately 436 sq. ft., or 112 sheets, 20 by 28 in. Long ternes are those with coatings of 8, 12, and 15 lb., not heavier than No. 14 gage or lighter than No. 30 gage. Short ternes are those with coatings of 8 lb. or lighter, or in very heavy coatings from 15 to 40 lb. for roofing use. The name long terne is thus sometimes used to designate flat sheets of the heavier

weights used for manufacturing purposes. The usual roofing material is 40 lb., and the coating is 25 per cent tin and 75 lead. Industrial terne plate usually comes in base boxes of 112 sheets, 14 by 20 in., furnished as standard, deep-drawing, and extra deep-drawing. When copper steel is specified, it has at least 0.18 per cent of copper.

**Terra-cotta.** A general English term applied to fired, unglazed, yellow and red clay wares; in the United States it refers particularly to the red and brown square and hexagonal tiles made from common brick clay, always containing iron. Some special terra-cottas are nearly white, while for special architectural work other shades are obtained by dyes. The clays are washed, and only very fine sands are mixed with them in order to secure a fine open texture and smooth surface. Terra-cotta is used for roofing and for tile floors, for hollow building blocks, and in decorative construction work. Good, well-burned terra-cotta cannot be more than 1½ in. thick. Terra-cotta is very light, 120 lb. per cu. ft., and will withstand fire and frost.

**Tetra-chlor-ethane.** A colorless liquid of the chemical formula $CHCl_2 \cdot CHCl_2$, employed as a solvent for organic compounds such as oils, resins, and tarry substances. It is also an excellent solvent for sulphur, phosphorus, iodine, and various other elements. It is also used as a paint remover and bleacher, as an insecticide, and in the production of other chlorine compounds. It is also called Acetylene tetrachloride, and is made by the combination of chlorine with acetylene. Tetra-chlor-ethane boils at 144°C., freezes at −36°C., and is noninflammable. It has a specific gravity of 1.601. It is narcotic and toxic, and the breathing of the vapors is injurious. Mixed with dilute alkalies, it forms explosive compounds. In the presence of moisture it is very corrosive to metals. Mixed with zinc dust and sawdust, it is employed as a smoke screen.

**Tetraethyl lead.** A liquid of the composition $Pb(C_2H_5)_4$, which is used to mix with gasoline to lower the rate of explosion to prevent knocking in the engine from the hammerlike blows of sudden explosions. It is volatile, and the fumes are poisonous. Only minute quantities are dissolved in the gasoline; the latter,

called Ethyl gasoline, is then always colored with dyes for identification. Ethyl fluid, for adding tetraethyl lead to gasoline, is marketed by the Ethyl Gasoline Corporation. Ethyl fluid is usually added to high-test gasolines. Tetrethyl lead is also used as an antioxidant to reduce the sludging of lubricating oils that are used at high temperatures.

**Tetralin.** A transparent liquid of the empirical formula $C_{10}H_{12}$, employed as a solvent for fats, oils, and resins. It burns with a clear flame and can also be used as a motor fuel. The specific gravity is 0.975, boiling point 206°C., melting point −28°C., and flash point 78°C. It is stable at ordinary temperatures. Tetralin is made by the hydrogenation of naphthalene.

**Tetra-nitro-aniline.** Commonly known as TNA. A high explosive derived from benzene by a complicated process of nitration. TNA is the strongest of all solid high explosives. It is a fine crystalline powder varying in color from greenish yellow to olive green. It is insoluble in water but soluble in acetone. The chemical formula is $O_2N{\cdot}NH_2(NO_2)_3$. It melts at 215°C. The specific gravity is 1.867. It stains the skin a yellow color but is not poisonous. TNA is more sensitive to shock than TNT, and due to its high cost has only a limited military and commercial use as an explosive. See Explosives.

**Tetryl.** A high explosive of the same class as TNT and TNA, also known as Pyronite. Tetryl is an aromatic nitro derivative of benzene, and chemically is called tetra-nitro-phenyl-methyl-aniline. It is a fine, crystalline yellow powder, insoluble in water but soluble in benzene and acetone. It melts at 130°C. and explodes when heated to 186°C. It is not hygroscopic. Tetryl is made by nitrating benzene, reducing with iron and muriatic acid, and then combining with methyl alcohol. The resulting dimethylaniline is again nitrated, and the tetryl separated out. The formula is $O_2N{\cdot}N{\cdot}O_2N{\cdot}CH_3(NO_2)_2$. Tetryl is more sensitive to shock than TNA, and has a rate of detonation higher than TNT. It is too sensitive to be used as a shell filler, and is employed as a booster explosive and in commercial explosives to replace mercury fulminate for detonators.

**Thallium.** A rare metallic element, symbol Tl. The metal resembles lead, is soft and malleable, and melts at 570°F. At about 600°F. it ignites and burns with a green light. Its specific gravity is about the same as lead. It is resistant to acids but is acted on by nitric and by sulphuric acids. Thallium is capable of forming alloys with many other metals. Alloys of lead and thallium, containing from 20 to 65 per cent of thallium, patented by C. G. Fink, are corrosion resistant and are used for depositing as a plate on parts for chemical machinery. A patented Lead-thallium alloy of the Westinghouse Electric and Manufacturing Company, containing up to 20 per cent of thallium, is used for soldering. The metal occurs in copper and iron pyrites and zinc ores, and the chief source is the flue dust of smelters. The salts of thallium are highly poisonous, the sulphide being used as a rat poison. Thallium oxysulfide is used in light-sensitive cells. It is also sensitive to infrared rays, and is used for dark signaling. Thallium has a crystalline structure and, when added to bearing metals, increases the strength and resistance to deformation.

**Thermit.** The trade name of a mixture of finely divided aluminum and pure iron oxide, which when ignited reacts to produce a superheated steel at a temperature of about 5000°F. The reaction depends upon the affinity of oxygen for aluminum. Up to a temperature of 2800°F. thermit is inert, but above that temperature the oxygen of the iron oxide unites with the aluminum, setting free the iron in molten form. It is used for the welding of heavy pipes and large sections of iron or steel. Red thermit is the mixture with red oxide of iron, and Black thermit is with the black oxide. Railroad thermit is plain thermit with the addition of 17 per cent of nickel, manganese, and mild-steel punchings, used for all steel welds. Cast-iron thermit is plain thermit with 3 per cent of ferrosilicon and 20 per cent of mild steel punchings, used for welding cast-iron parts. The thermit is melted by the heat of its own chemical reaction, and the combustion is started by means of a gas torch, or with a special powder. The original patents on the thermit process are held by the Goldschmitt Thermit Company.

**Thermoelectric metals.** Also called Thermostatic metals, or Thermocouple metals. Metals or alloys used in thermocouples for measuring high temperatures. When two wires of different metals are joined, any application of heat to the coupled end will set up an electric current in the metallic circuit. Such a couple is connected by wires to a sensitive galvanometer. The electromotive force is proportional to the temperature at the junction; a reading of the indicator thus gives the temperature. Accuracy within a range of 2°F. in temperature readings can be obtained for high-temperature readings. Metals for thermocouples must be refractory, and must be selected to give the greatest possible electromotive force since the electric current generated is extremely small, about 50 millivolts. These bimetals are usually made in thicknesses from 0.008 to 0.250 in. One maker produces the metals in grades up to 650 ohms per sq. mil ft. Thermoelectric metals in use are platinum, rhodium, iridium, nickel, iron, copper. Usually they are special alloys of these metals such as Chromel, Nichrome, and Alumel. A copper-Constantan couple is used for temperatures up to 800°F., an iron-Constantan or nickel-Constantan up to 1650°F., a Chromel-Alumel up to 2200°F., and a platinum-platinum rhodium up to 2600°F.

Thermometals, used for indicating temperatures from about −40 to 1000°F., consist of two metals or alloys with different rates of thermal expansion bonded together so that with a change of temperature the bimetal bends or deflects. In heat-control or indicating devices the deflection is measured to indicate the temperature, or the deflection is utilized for mechanical or electrical action. A wide variety of metals is used for thermometal couples. The requirements are corrosion resistance, heat resistance, and uniform pull proportional to the temperature change. Thermometals bonded or welded at the contact surfaces are marketed under various trade names. Highflex is a thermometal of the H. A. Wilson Company.

**Thorite.** A rare mineral which is a source of thorium. It is found chiefly in Norway. Thorite is a thorium silicate, $ThSiO_4$, sometimes also containing uranium. It occurs in

crystals or massive, with a resinous luster and color orange, brown, or black. The specific gravity is 4.8 to 5.2, and the hardness is 5 Moh.

**Thorium.** A rare metal which, in the form of Thorium nitrate, $Th(NO_3)_4$, is used for incandescent gas mantles. The metal is never used in a pure state due to its high melting point and the ease with which it combines with oxygen. The impure metal is a gray powder with a specific gravity of 11.3. It burns easily in the air with great brilliance. The melting point is placed at 3090°F. The chief source of thorium nitrate is in the mineral monazite found in Brazil, India, East Africa, and to some extent in the United States. Ceylon monazite usually contains about 10 per cent of thoria, or double that of Brazil. Monazite is a sand varying in color from yellow to dark brown. The thorium is separated from the cerium, yttrium, lanthanum, and other elements in the monazite by a complicated process. The incandescent mantle, invented by Welsbach in 1893, used a mixture containing 98 to 99 per cent of thorium oxide and 1 to 2 per cent of cerium oxide. The thorium nitrate is converted to the oxide by ignition, with an increase of 10 times its volume. Thorium compounds are used in flashlight powders. Thorium oxide, or Thoria, $ThO_2$, is produced from Monazite sand, the Brazilian beach sand containing up to 8 per cent of thoria. It has a high melting point, 3000°C. and is used for crucibles, but its use as a refractory is limited because of its cost and because of its sensitiveness to sudden temperature changes.

**Tin.** A silvery-white lustrous metal with a bluish tinge. The chemical symbol is Sn. It has been employed from the earliest times. Tin is soft and very malleable. It can be rolled into sheets as thin as 0.0002 in. It melts at 232°C.; and has a specific gravity of 7.298. It is dissolved by mineral acids. When rubbed it gives a peculiar odor, and when bent gives a peculiar cracking, or crying sound. Tin pest is the breaking up of the metal into a gray powder. This action occurs below 18°C. Tin is used as a protective coating for other metals against corrosion, as a solder, and in bronze alloys and babbitts. Electroplated tin gives a fine white color which is corrosion resistant. It also

gives a lubricating effect on wearing surfaces, and is thus used for plating on airplane engine pistons and rings. The chief source of tin is cassiterite, but Nigerian columbite contains about 6 per cent of tin oxide. The principal tin-producing countries are the Dutch East Indies, Malay Peninsula, and Bolivia. The Standard tin of the London Metal Exchange must contain over 99.75 per cent tin. Chempur tin is 99.997 per cent pure. Federal specifications for Pig tin call for two grades, 98 and 99.75 per cent. Block tin is virgin tin cast in stone molds. Even small traces of impurities have an influence on tin. Lead softens the metal; arsenic and zinc harden it. An addition of 0.3 per cent of nickel doubles the tensile strength of tin; 2 per cent of copper increases the strength 150 per cent. Pure tin melts sharply, but small amounts of impurities broaden the melting period. About 45 per cent of the American consumption of tin is for tin plate, and 15 per cent for solder.

**Tin foil.** Very thin sheet tin used for wrapping confectionery and food products. It was formerly also used for wrapping other materials, but due to its high cost has been largely replaced with aluminum and lead foils. Ordinary tin foil is made in thicknesses from 0.006 mm. (0.00024 in.) to 0.200 mm. (0.00787 in.), the former having 16,037 sq. in. per lb., and the latter 432 sq. in. per lb. Tin foil for use in radio condensers has 14,500 sq. in. per lb.

**Tin oxide.** Also called Stannic oxide. A fine white crystalline powder of the composition SnO, used as an opacifier in ceramic enamels, as a ceramic color, and also as an abrasive. See Enamels and Putty powder. It is made by oxidizing tin powder in a flame. The specific gravity is 6.9 and refractive index 2.04. When mixed and fired with magnesium and cobalt oxides, it gives a sky-blue color called Cerulean blue. It gives rose-red and reds with other materials. Tin oxide is permanent to light and is acid resistant in ceramics.

**Tin plate.** Soft-steel plate containing a thin coating of pure tin on both sides. A large proportion of the tin plate used goes into the manufacture of food containers because of its resistance

to the action of vegetable acids and its nonpoisonous character. It solders easily, and also is easier to work in dies than terne plate, so that it also is preferred over terne plate for making toys and other cheap articles in spite of a higher cost. Commercial tin plate comes in boxes of 112 sheets, 14 by 20 in., and is designated by the net weight per box when below 100 lb. Heavy tin plate above 100 lb. goes by number as with sheet steel, or by letter symbols. The weight of tin is usually 1.5 to 1.7 per cent of the total weight of the plate. Coke plates carry as little tin as is necessary to protect and brighten the plates for temporary use. "Best cokes" carry more tin than do the standard cokes. Charcoal plates have heavier coats of tin designated by the letter A. The AAAAAA, or 6A, has the heaviest coating. Tin plate is made by the hot-dip process using palm oil as a flux. Taggers was originally a name for tin plate which is undersized, or below the gage of the plate in the package, but the name Taggers tin is also applied to light-gage plate. These sizes are No. 38 gage, 55 lb.; No. 37, 60 lb.; and No. 36 gage, 65 lb. Ductillite, of the Wheeling Steel Corporation, is a tin plate not made by hot rolling in packs, but is cold-rolled from single hot-rolled strip steel. It is of uniform gage and does not have the thin edges of pack-rolled plate. It also has a uniform grain structure.

**Titanium.** A metallic element, symbol Ti, occurring in a great variety of minerals. Its chief commercial ores are rutile and ilmenite. In rutile it occurs as an oxide. It is an abundant element, but is often considered as a rare metal due to the difficulty of separating it. It has a strong affinity for oxygen, hydrogen, and carbon. The pure metal has a silvery-white color and is extremely hard, cutting glass with ease. It can be forged when red hot, but when heated to 600°C. in oxygen it burns to titanic oxide. Its melting point is very high, 3272°F., but it dissolves easily in molten copper. The specific gravity is 4.50. The ore is reduced by calcium shavings or calcium hydride to produce metallic titanium in powder form, which is sintered and rolled into sheets. The pure metal, free from oxides, is ductile, but the metal normally contains oxides and is brittle.

Titanium is used in the form of ferrotitanium for purifying steel. It is also used in alloy steels to increase the tensile strength and the hardness. A patent held by the Metal & Thermit Corporation covers the use of titanium instead of vanadium in high-speed steel. A titanium steel produced by the Société Titanor, France, under the name of Titanor metal, is employed for making punches, shear blades, and other tools. Titanium is also added to some heat-resistant steels and irons to prevent the combination of molybdenum or other alloying elements with the carbon. A Krupp patent covers steel of this type. When added to cast iron in quantities greater than 1 per cent, it toughens the iron remarkably, but is expensive for use in iron alloys. Small quantities of titanium in cast iron close the grain and act as a graphitizer. Titanium is alloyed with copper in strong bronzes. Its salts are used in arc-lamp electrodes, as mordants in dyeing, for yellow coloring of ceramics, and for pigments. Titanium carbide is used in the same manner as tungsten carbide for cutting tools. See Kennametal.

**Titanium-copper.** An alloy of titanium and copper employed for adding to molten metals as a deoxidizer. It is made by first melting the copper and dropping in the correct amount of titanium inclosed in a copper cup. In alloying, the copper foams greatly. Titanium-copper cannot be poured owing to its great viscosity, but is congealed around a shaft and broken when cold.

**Titanium oxide.** The white Titanium dioxide of the composition $TiO_2$, which is an important paint pigment. It is produced from ilmenite, and is higher in price than many white pigments but has great hiding power. It is also substituted for zinc oxide and lithopone in the manufacture of white rubber goods, and for paper filler. The specific gravity is about 4. Mixed with blanc fixe it is also marketed under the name of Titanox. Zopaque, of the Chemical & Pigment Company, is a pure titanium oxide for rubber compounding.

**Titanium tetrachloride.** A colorless liquid of the composition $TiCl_4$ used for making smoke screens and for "sky writ-

ing." In moist air it forms dense, white fumes of titanic acid, $H_2TiO_3$, and hydrogen chloride. The specific gravity is 1.727 and boiling point 136°C. It is also used as a mordant. As a smoke agent it was called F-stoff by the Germans.

**Toluene.** Also called Methyl-benzene, and Toluol. A liquid of the composition $C_6H_5CH_3$, resembling benzene. It is obtained from by-product coke ovens and from petroleum and is the basis of many dyes, explosives, and aromatic compounds. Toluene is also obtained by distilling sulphite turpentine with aluminum chloride in the presence of hydrochloric acid. It has a specific gravity of 0.871, boiling point of 110°C., and solidifying point of −95°C. It is inflammable and poisonous. It has an odor distinct from that of benzene. T oil is a sulphur-toluene condensation product made under a British patent and used as a plasticizer for chlorinated rubber. Large quantities of toluol are used for solvents. See also TNT.

**Tool steel.** A high-carbon steel used for making tools. It has the property of becoming extremely hard by quenching from a temperature of 1400 to 1800°F. It can then be "drawn" to any degree of hardness by heating at lower temperatures. The original tool steels were accidental combinations produced by uniform expert processes rather than by alloying. One of the earliest recorded tool steels was the ancient Chalybeate steel, originally referring to steel from the Chalybes in Pontus. The unqualified term tool steel does not usually include special alloy steels containing nickel, manganese, and other metals, nor high-speed steels. However, tool steels for special purposes may contain many other elements besides carbon. The possibilities of percentage combinations of vanadium, nickel, manganese, chromium, silicon, tungsten, and other elements in alloy tool steels are infinite; as there are nearly a thousand trade-named steels on the market, the name Carbon tool steel is used to designate tool steel containing only carbon, and with other elements below perceptible amounts. See Alloy steel and Carbon steel.

Tool steel may contain from 0.65 to 1.50 per cent of carbon, the lower-carbon grades, up to 0.90 carbon, being used for

punches, hammers, chisels, and other tools requiring some degree of elasticity, and the high-carbon grades are used for dies, drills, and edge tools. Files, saws, and engraving tools may contain up to 1.60 per cent of carbon. The manganese content is 0.20 to 0.30. Razor steel was steel with 1.5 per cent carbon, but razors are now usually made of alloy steels. Beyond 1 per cent of carbon, there is an excess of carbon and the steels become very brittle when hardened. Theoretically, the maximum point of solution of the $Fe_3C$ in a plain carbon steel is at 0.85 per cent of carbon, but when other elements are present other carbides are formed giving greater hardness and strength above this point. The ideal maximums of phosphorus and sulphur in a tool steel are 0.025 per cent, with silicon at 0.20 and manganese at 0.25, but in special steels the silicon and manganese are increased.

The lower temperature ranges are used for hardening high-carbon steels and thin pieces. Some steel makers grade carbon steels by divisions as low as 5 "points" of carbon. Pompton tool steel, of the Ludlum Steel Company, has 19 grades from 0.50 per cent of carbon to 1.45 carbon. Modern carbon tool steels for ordinary water hardening, with or without residual vanadium, develop remarkable physical properties. Ryerson VD die steel, as quenched, has a hardness of 725 Brinell, or 96 Scleroscope.

Oil-hardening tool steels usually contain about 1 per cent of manganese, but mild-alloy tool steels may contain less, with other elements. CM and CMM tap steels, of the Colonial Steel Company, are oil-hardening, keen-edge steels; CM contains 0.50 per cent chromium, 0.60 manganese, and 1.20 carbon; CMM contains 0.50 chromium, 0.85 manganese, 0.60 molybdenum, and 1.20 carbon. These steels have high torsional strength.

Tool steel comes regularly in round, square, and octagon bars, and in flats, but drawn shapes are also available. Tool steels require more care in forging than low-carbon machinery steels and they are more difficult to machine. The quality of the steel is dependent upon the method of melting, rolling, and forging as well as upon the composition. The smallest

possible grain size, and freedom from nonmetallic inclusions, are the qualities sought. A.S.V. steel, of the Firth-Sterling Steel Company, is made by a patented winged ingot form of casting in order to eliminate any porosity in the center. Carbon-vanadium tool steels are produced in all carbon contents with about 0.20 per cent of vanadium. They have a uniform fine grain, and constitute a class of "super" carbon tool steels. See Vanadium steel. Some steels for special purposes contain more vanadium. Colhead steel, of the Vanadium Alloys Steel Company, for cold-heading dies, has 0.45 per cent vanadium and 1 carbon. Vatool, of the Henry Disston & Sons, Inc., is a vanadium tool steel for taps. See also Nondeforming steels, Finishing steel, Chromium steel, High-speed steel, Hot-die steel.

**Toon.** The wood of the tree *Cedrela toona* of India, Burma, Java, and Australia. It is called Moulmein cedar in England and is also known as Indian mahogany. The wood is almost indistinguishable from the Spanish cedar of tropical America. If seasoned well the wood does not warp and is durable. It is easily worked and takes a fine polish. The weight is about 35 lb. per cu. ft. The color is a deep red, and the grain has a beautiful appearance. It is used for boxes, cabinetwork, furniture, and construction.

**Tracing cloth.** A thin, fine cotton or linen fabric, of plain weave, heavily sized and glazed on one side. It is used for making tracings in ink and is quite transparent. It can also be obtained with the glaze on both sides. Tracing cloth is usually marketed in rolls of 24 yd. The sizing is easily soluble in water, and the cloth will therefore not withstand wetting.

**Tragacanth gum.** An exudation of the shrub *Astragalus gummifer* of Asia Minor and Persia, used in adhesives or for mucilage, for leather dressing, for textile printing, and as an emulsifying agent. To obtain the gum a small incision is made at the base of the shrub, from which the juice exudes and solidifies into an alteration product, not merely the dried juice. The gum derived from the first day's incision, known as Fiori, is the best quality, and is in clear fine ribbons or white

flakes. The second incision produces a yellow gum known as Biondo. The third incision produces the poorest quality, a dark gum known as Sari. Rainy weather during the incision period may cause a still inferior product. Tragacanth is insoluble in alcohol but is soluble in alkalies and swells in water.

**Trichlorethylene.** A heavy colorless liquid of pleasant odor of the composition $CHCl:CCl_2$, also known as Westrosol, and popularly known as "Tri," employed as a solvent. It is obtained by heating tetra-chlor-ethane with milk of lime and distilling in steam. Its boiling point is 87°C. and specific gravity 1.471. It is insoluble in water and is unattacked by dilute acids and alkalies. It is not inflammable and is less toxic than tetra-chlor-ethane. Trichlorethylene is a powerful solvent for fats, waxes, resins, rubber, and other organic substances, and is employed for the extraction of oils and fats, for cleaning fabrics, and for degreasing metals preparatory to plating. The freezing point is −88°C., and it is also used as a refrigerant. It is also used in soaps employed in the textile industry for degreasing. Tri-Clene is a trade name of E. I. du Pont de Nemours & Company, Inc., for trichlorethylene, marketed for dry-cleaning.

**Trinitrotoluene.** Known commonly as TNT, and also as Trinitrotoluol. The principal constituent of many explosives. TNT was first described in 1863, but not used as a military explosive until 1904. It resembles in appearance powdered brown sugar. The chemical formula is $C_6H_2(CH_3)(NO_2)_3$. It is not as powerful as picric acid, but is not hygroscopic, and does not form unstable compounds. It melts at about 80°C. The fumes are poisonous, and it is also absorbed through the skin and is a cumulative poison. It is the most stable of high explosives, but is detonated readily with mercury fulminate. It is employed for shrapnel, hand grenades, drop bombs, mines, and depth bombs. TNT is made by the nitration of toluene with a mixture of nitric and sulphuric acids. The intermediary product, dinitro-toluene, is employed with hexa-nitro-diphenylamine for torpedoes. A commercial explosive, known as Sodatol, is made by mixing TNT with nitrate of soda.

**Tripoli.** A name given to finely granulated, white, porous, siliceous rock, used as an abrasive and as a filler. True tripoli is an infusorial diatomaceous earth known as Tripolite, and is a variety of opal, or Opaline silica. In the abrasive industry it is called Soft silica. It is quarried in Missouri, Illinois, eastern Tennessee, and Georgia. Pennsylvania rottenstone is not tripoli, although it is often classed with it. The material marketed for oil-well drilling mud by the Corona Products, Inc., under the name of Opalite, is an amorphous silica. The Missouri tripoli ranges in color from white to reddish, and the crude rock has a porosity of 45 per cent, and contains 30 per cent or more of moisture. It is air dried and then crushed and furnace dried. Tripoli is used in massive form for the manufacture of filter stones for filtering small supplies of water. Missouri tripoli is also used for the manufacture of foundry parting. Tripoli finely ground, free from iron oxide, is used as a paint filler and in rubber. The grade of tripoli known as O. G. (once ground) is used for buffing composition, D. G. (double ground) for foundry partings, and the air-float product for metal polishes. Tripoli grains are soft, porous, and free from sharp cutting faces, and thus give a fine polishing effect. It is the most commonly used polishing agent. Tripoli compounds are sold under many trade names.

**Tung oil.** The most powerful drying oil known, having almost double the rapidity of linseed oil. It is used for enamels and varnishes. Tung oil is pressed from the seeds of the *Aleurites cordata*, a plant which grows extensively in China and Japan. It is also known as China wood oil. The seeds, or nuts, contain 53 per cent of oil. The color varies from golden yellow to dark brown according to the degree of heat used in extraction. It has a pungent odor resembling that of bacon fat. A good grade of raw tung oil should have a specific gravity between 0.943 and 0.940, a saponification value of 190, and an iodine value of 163. The oil has the property of drying throughout at a uniform rate instead of forming a skin as does linseed oil, but it dries flat instead of glossy like linseed oil. It is mixed with rosin since rosin has great affinity for it, and the two together are

suitable for gloss varnishes. The tree *A. fordii* has also been cultivated in the South of the United States for the production of tung oil. The annual yield is about 30 lb. of oil per tree.

**Tungsten.** An elementary metal, symbol W, never found free in nature. Its commercial ores are wolframite, ferberite, scheelite, and hübnerite. The important sources of tungsten ores are India, Argentina, China, Australia, Europe, and the United States, half of the world's production coming from China, but the ores are very widely distributed in small quantities. See Wolframite and Scheelite. The metal was produced first in metallic form in 1783, but was not used alone until developed as a filament for incandescent lamps in 1904. Tungsten is a heavy white metal with specific gravity of 19.6 and melting point 6100°F. The Brinell hardness is 290. It is obtained in powder form by reduction of the oxide $WO_3$ in a stream of hydrogen. The powder is pressed into rods, then heated to 3000 or 3200°C., forming a dense brittle rod. It is worked until it becomes ductile. In ordinary tungsten metal the grains are large, not over 1,500 per sq. mm.; for special purposes, such as for electric contacts, tungsten is produced with as high as 80,000 per sq. mm. The tensile strength of rolled sheets is as high as 500,000 lb. per sq. in. Wire drawn to a diameter of 0.0014 in. has a strength of 590,000 lb. per sq. in., the greatest tensile strength of all the metals. Sheets are available in thicknesses from 0.001 to 0.062. It is not attacked by nitric, hydrofluoric, or sulphuric acid solutions. Tungsten wire is used for electric lamp filaments and contact points, but the chief use of tungsten is in high-speed steels and special-alloy steels. Tungsten is usually added to iron alloys in the form of ferrotungsten, but also in the form of Tungsten powder, which is the commercially pure metal in powder form, melting at about 6000°F., and being 95 to 98 per cent pure tungsten. Tungsten salts are used for bronze powders, and also as mordants in dyeing.

**Tungsten carbide.** An iron-gray powder of minute cubical crystals, having the composition WC. The specific gravity is about 16 and the hardness is 9.8 to 9.9, or nearly that of the diamond. The melting point is about 5400°F., but if strongly

heated it may decompose into $W_2C$ and carbon, and the commercial carbide may be a mixture of WC and $W_2C$, with a hardness of about 9.5. Tungsten carbide is produced by carbonizing incandescent tungsten in a methane or hydrocarbon vapor, and other forms may be produced, $W_2C$, $W_3C$, and $W_3C_4$. Another method of production is by heating tungsten powder and carbon in a furnace. Tungsten carbide is used as an abrasive, or is briquetted with cobalt or other binders into tools for the high-speed cutting of metal or for cutting hard materials.

The briquetted and sintered product is harder than any commercial steel and will scratch sapphire. Briquetting of tungsten carbide into usable form was first patented in Germany and produced by the Krupp Works under the name of Widia metal. It is made by diffusing powdered cobalt through the finely divided carbide under hydraulic pressure, and then sintering in an inert atmosphere at about 1500°C. The briquetted material is then ground to shape, and the pieces are brazed to tools. They will withstand cutting speeds from three to ten times those of high-speed steel, but will not withstand shocks. However, they are used to replace diamonds in oil-well boring tools. Tungsten carbide sintered materials are sold under many trade names such as Camite, of the Cleveland Automatic Machine Company, Dimondite, of the Firth-Sterling Steel Company, Haystellite, of the Haynes Stellite Company, Armide, of the Armstrong Bros. Tool Company, Strauss metal, of the Ludlum Steel Company. Perdurum, Phoran, and Hartmetall are European tungsten carbides.

Wilcoloy is a tungsten-carbide material of the H. A. Wilson Company used for telegraph relay contact points. Talide, of the Metal Carbides Corporation, is a tungsten-carbide wear-resistant metal used for bushings, lathe centers, and gage surfaces. Borium, of the Stoody Company, is used for facing oil-well drills. Borod, of the same company, is the material encased in a metallic tube used as a welding rod for facing wearing parts. Firthite, of the Firth-Sterling Steel Company, is a mixture of tungsten and other carbides for cutting tools. Firthaloy is a special grade for wire-drawing dies. Carboloy, of the Carboloy Company, Inc., is a material for cutting tools,

drawing dies, and facing blocks, made in several grades of tungsten carbide, tantalum carbide, titanium carbide, or combinations. It has a compressive strength of 700,000 lb. per sq. in. and a transverse rupture strength up to 295,000 lb. per sq. in. Kennametal, of the McKenna Metals Company, is $WTiC_2$, with a binder metal used for cutting tools. Small amounts of titanium carbide are added to cemented tungsten carbide to give greater cutting efficiency. Cutanit, of the Firth Sterling Steel Company, is a mixed material of this class.

**Tungsten paste.** Various plastic oxides of the metal tungsten employed for the production of metallic fibers for electric lamp filaments. They were originally covered by English and French patents and were prepared by boiling hydrated tungsten oxide with ammonia until it crystallizes. The crystals are removed and the residue boiled with water into a plastic mass which can then be squirted into filaments. The violet oxide $W_2O_5$, and the brown oxide $WO_2$ are most suitable for this purpose. Colloidal tungsten, formerly extensively employed for the production of electric lamp filaments, was prepared by passing an electric arc between tungsten electrodes under water and then evaporating into a plastic mass.

**Tungsten steel.** Any steel containing tungsten as the alloying element imparting the chief characteristics to the steel. It is one of the oldest of the alloying elements in steel, the celebrated ancient Eastern sword steels having had tungsten in them. Tungsten increases the hardness of steel, and also gives it the property of red hardness. Very small quantities serve to produce a fine grain and raise the yield point. The tungsten forms a very hard carbide and an iron tungstide, and the strength of the steel is also increased, but it is brittle when the tungsten content is high. Tungsten steels, except the low-tungsten chromium-tungsten steels, are not suitable for construction, but tungsten steels are widely used for tools. The alloys are difficult to forge, and cannot be readily welded when the tungsten exceeds 2 per cent. Standard S.A.E. tungsten steels, S.A.E. 71360, and S.A.E. 71660, contain 12 to 15 and 15 to 18 per cent of tungsten, respectively, with 3 to 4 per cent of chro-

mium and 0.50 to 0.70 carbon. S.A.E. 7260 contains 1.5 to 2 per cent tungsten and 0.50 to 1 chromium.

When the tungsten content is high, particularly when the steel contains manganese also, the steel can be hardened by air cooling. These alloy steels have a close, uniform texture, and tools made from them will keep an edge when hot; for cutting tools tungsten steels with other alloying elements are used. See High-speed steel. In annealing tungsten steels the stable carbide WC may be formed; to prevent this, chromium is used as an inhibitor. A low tungsten steel for taps and cutters contains 1.5 to 2.0 per cent of tungsten, 1 to 1.3 carbon, with a small amount of chromium and vanadium. See Finishing steel. Maxtack steel, of A. Milne & Company, for tack and nail dies, has 10 per cent of tungsten, 2 chromium, 2.5 manganese, 1 silicon, and 2.25 carbon. It is self-hardening. O.K. steel of William Jessop & Sons, used for chisels and punches, has 2 per cent of tungsten with only 0.40 carbon. It is hard but very shock resisting. A Firth-Sterling Steel Company chisel steel, sold under the name of J-S steel, has 2.25 per cent of tungsten, 1.4 chromium, 0.50 carbon, and a trace of vanadium. It is also used for cutters, punchers, and shear blades. Buster steel, of the Columbia Steel Company, is a similar steel, but has less chromium with more vanadium. Wizard steel, of the Ziv Steel and Wire Company, used for pneumatic tools, riveter dies, and swaging dies, has 1 per cent of tungsten, 1 of chromium, 0.35 carbon, and a small amount of molybdenum. At a hardness of 55 Rockwell it has great toughness and resistance to shock. A wear-resistant tool steel for finishing tools and gages, but not in the class of die steels, contains about 1.6 per cent tungsten, 0.42 chromium, 0.20 vanadium, and varying amounts of carbon up to 1.25 per cent. Chimo steel, of the Firth-Sterling Steel Company, used for pneumatic chisels, is a tough, air-hardening steel with high fatigue resistance.

Steels with from 4 to 6 per cent of tungsten, 2 to 6 per cent of chromium, 0.40 to 1.80 manganese, and 0.40 carbon are used for dies for die casting, and give long life in contact with the molten casting metals. Steels with as high as 10 per cent of tungsten and 3.5 per cent chromium are used for die blocks for hot forging.

See Hot-die steels. High-carbon tungsten steels retain a high magnetism, and are used for magnets. See Magnet steel.

**Turbadium bronze.** The name of a brass containing iron and manganese used for casting propellers and marine parts. The turbadium bronze used by the British Admiralty for propellers for warships contains 50 per cent of copper, 44 zinc, 1 iron, 1.75 manganese, 2 nickel, and 0.5 tin. This metal resists corrosion better than manganese bronze. Some turbadium bronzes made in the United States also contain about 2 per cent of aluminum. See Superbronze. Another bronze intended for high resistance to sea water is Turbiston's bronze. A typical composition is 55 per cent of copper, 41 zinc, 1 aluminum, 2 nickel, and 1 iron.

**Turkey red oil.** A name given to sulphonated castor oil used for the preparation of cotton fiber to be dyed. It gives clearer and brighter colors. The lower grades of castor oil are employed for making turkey red oil, and are treated with sulphuric acid and washed with a solution of sodium sulphate. Turkey red oil is miscible with water and lathers like a solution of soap. It is used in soaps to increase the lathering and the solubility in cold water, and is also used in cutting compounds.

**Turpentine.** Also called in the paint industry Oil of turpentine and Spirits of turpentine. An oil obtained by steam distillation of the oleoresin which exudes when various conifer trees are cut. Longleaf pine and Slash pine are the main sources. It also includes oils obtained by distillation and solvent extraction from stumpwood and waste wood. Longleaf sapwood contains about 2 per cent of oleoresin, heartwood 7 to 10 per cent, and stumpwood 25 per cent. Most oleoresin is obtained from the sapwood of living trees, but it is not the sap of the tree. Heartwood resin is obtained only when the cut wood is treated with solvents. See Wood turpentine. The oleoresin yields about 20 per cent of oil of turpentine and 80 per cent of rosin, both of which are known as Naval stores. See Rosin. Turpentine varies in composition according to the species of pine from which it is obtained. It is produced chiefly in the United States, France, and Spain. The turpentine of India comes from the Chir pine, *Pinus*

*longifolia*, of the southern slopes of the Himalayas, also valued for lumber, and the Khasia pine, *P. khasya*. The gum of the chir pine is different from American gum, and the turpentine, unless carefully distilled, is slower drying and greasy. French and Spanish turpentine is from the Maritime pine, *P. pinaster*, which is the chief source, and from Aleppo pine, *P. halepensis*, and Corsican pine, *P. laricia*. In Portugal, the Stone pine, *P. pinea*, is the source. Venetian turpentine is from the Corsican pine or European larch. The French maritime pine is also grown on plantations in Australia. Aleppo pine of Greece was the source of the naval stores of the ancients. European pines do not give as high a yield as American longleaf and slash pines. American turpentine oil boils at 154°C., and the specific gravity is 0.860. It is a valuable drying oil for paints and varnishes due to its property of rapid absorption of oxygen from the atmosphere and transferring it to the linseed or other drying oil, leaving a tough and durable film of paint. Turpentine is also used in the manufacture of artificial camphor and rubber, and in linoleum, soap, and ink. It is often adulterated with other oils of the pine or with petroleum products, and the various states have laws regulating its adulteration for paint use. Gum thus, used in artists' oil paints, is thickened turpentine. See also Mercus pine.

**Type metal.** Any metal used for making printing type, but the name generally refers to lead-antimony-tin alloys. The antimony has the property of expanding on cooling, and thus fills the mold and produces sharp, accurate type. The properties required in a type metal are ability to make sharp, uniform castings, strength and hardness, fairly low melting point, narrow freezing range to facilitate rapid manufacture in type-making machines, and resistance to drossing. A common type metal is composed of 9 parts of lead to 1 of antimony, but a great variety of other mixtures are also used. The antimony content may be as high as 30 per cent, 15 to 20 per cent being frequent. A common monotype metal has 72 per cent lead, 18 antimony, and 10 tin. Larger and softer types are made of other alloys, sometimes containing bismuth; the hardest small type contains 3 parts of lead to 1 of antimony. A low-melting-point, soft type metal contains

22 per cent of bismuth, 50 lead, and 28 antimony. It will melt at about 310°F. Copper, up to 2 per cent is sometimes added to type metal to increase the hardness, but is not ordinarily used in metals employed in rapid-acting type machines. Since zinc causes drossing, it is avoided in all type metals. German and English practice employs fairly large amounts of bismuth. Standard linotype-machine metal for pressure casting has 79 per cent of lead, 16 antimony, and 5 tin. Monotype metal has 10 to 13 per cent of antimony and 2 to 5 tin. Stereotype metal, for sharp casting and hard wearing qualities, is given as 83.75 per cent lead, 11.75 antimony, 4 tin, and 0.50 copper. Intertype metal has 11 to 14 per cent of antimony and 3 to 5 tin. The Brinell hardness of machine-molded type ranges from 17 to 23, and that of stereotype metal is up to 30. As constant remelting causes the separation of the tin and lead, and also the loss of tin, or "impoverishment" of the metal, new metal must be constantly added to prevent deterioration of a standard metal into an inferior alloy.

**Ultramarine.** An important blue pigment, used in printing and paints. It is also used as a blue for whitening the yellow of paper, starch, sugar, and fabrics. Ultramarine was formerly obtained by grinding lapis lazuli, but is now made by calcining a mixture of aluminum silicate and sodium sulphide. Ultramarine blue is ground, and is sold as a deep-blue crystalline powder of 325 mesh, insoluble in water. It may also come mixed with oil, and such a paste should contain 70 per cent of pigment and 30 of linseed oil. It is a double silicate of sodium and aluminum, $Na_2Al_2SiO_8 \cdot Na_2S$. Green ultramarine is obtained as an intermediate product. White, red, yellow, and violet ultramarines are obtained by various methods. Cheaper grades of ultramarine may be adulterated with gypsum or other materials.

**Umber.** A brown siliceous earth colored naturally with hydrated iron oxides and manganese oxide, used as a paint pigment. It comes chiefly from Italy and Cyprus. For use as a pigment it is washed with water and finely ground. It is inert and very stable. Burnt umber is redder in color than umber, and is made by calcining the raw umber. Caledonian brown and Cappagh brown are varieties of umber found in Great Britain.

**Upholstery leather.** Very thin, finely finished leather used for automobile upholstery, seats, and coverings for various articles. It consists of split hides, tanned to a soft, even texture, and usually dyed in colors. Chrome tanned leather is softer and stronger than ordinary leather tanned with barks or quebracho. In splitting, the full hide thickness of about 1/4 in. can be split into three or four thicknesses. After splitting, the leather is retanned and "nourished" with cod oil. Hand buffs are top grains with the top of the grain snuffed off. The second split of 3/64 in. is called deep buff, and has an artificial grain put on. The third split is called No. 2 split, and what remains is called a slab and is unsuited for upholstery leather. Splitting with four cuts gives Buffing, Machine buff, No. 1 split, No. 2 split, and Slab. Upholstery leather is finished by japanning, by coating with lacquer, by dyeing with aniline, or by combinations of the latter with either of the first two methods. Spanish leather, used for upholstery, is made by tanning the hides in strong quebracho liquor which draws the grain and gives a slight wrinkled appearance. See also Leather fabric.

**Uraninite.** Also called Pitchblende. It is the chief source of the elements radium and uranium. The mineral is a combination of the oxides of uranium $UO_2$ and $UO_3$, together with small amounts of lead, thorium, yttrium, cerium, nitrogen, helium, argon, and radium. The process of separation of radium is chemically complicated. The structure of uraninite is usually massive or in grains. The color is black, with pitchlike luster. The specific gravity is 9 to 9.7 and the hardness is 5.5. Uraninite is found with the ores of silver and lead in Saxony, Bohemia, and Hungary, and with tin ores in Cornwall, England. In the United States it occurs in pegmatite veins, and in the mica mines in North Carolina, and in Utah and Colorado. The richest ores come from the Belgian Congo. Autunite, also called Uranite, is a secondary mineral from the decomposition of pitchblende. The composition is approximately $P_2O_5 \cdot 2UO_3 \cdot CaO \cdot 8H_2O$. It is produced in Utah.

**Uranium.** An elementary metal, symbol U, which belongs to the same group as tungsten and chromium. It never occurs free

in nature but is found chiefly as an oxide. The principal source is from the mineral pitchblende where it is associated with radium. The metal has a specific gravity of 18.68 and atomic weight 238.2. The melting point is about 1860°C. It is hard but malleable, resembling nickel in color, but related to chromium, tungsten, and molybdenum. It is soluble in mineral acids. The metal is alloyed with iron to make Ferrouranium, used to impart special properties to steel. It increases the elastic limit and the tensile strength of steels, and is also a more powerful deoxidizer than vanadium. It is also used to denitrogenize steel. It is used in high-speed steels in amounts of 0.05 to 5 per cent to increase the strength and toughness. Uranium is more expensive than vanadium, and the losses from oxidation in adding to steel are greater. In cast iron small quantities of uranium, up to 1 per cent, increase the strength, toughness, and fluidity of the iron. Metallic uranium is used as a cathode in photoelectric tubes responsive to ultraviolet radiation. Uranium compounds, especially the uranium oxides, are used for making glazes in the ceramic industry and also for paint pigments. Carnotite is the chief ore.

**Uranium yellow.** Also called Yellow oxide and Sodium uranate. A sodium diuranate of the composition $Na_2U_2O_7 \cdot 6H_2O$, obtained by reduction and treatment of the mineral pitchblende. It is used for yellow and greenish glazing enamels and for imparting an opalescent yellow to glass, which is green in reflected light. Uranium oxide is an olive-green powder of the composition $U_3O_8$, used as a pigment. Uranium trioxide, $UO_3$, is a yellow powder also used for ceramics and pigments. It is also called Uranic oxide. As a pigment in glass it produces a beautiful greenish-yellow Uranium glass; Uranous oxide, $UO_2$, gives glass a fine black. Sodium uranate, $Na_2UO_4$, is a yellow to orange powder used to produce ivory to yellow shades in pottery glazes. The uranium oxide colors give luster and iridescence.

**Urea-formaldehyde resins.** Synthetic resins used for plastic molding and for adhesives and lacquers, which belong to the group known as Amino-aldehyde resins made by the interaction of an aldehyde and an amine. See Synthetic molding resins. The urea resins are made by the condensation of urea or thiourea

with formaldehyde. An initial condensation product is obtained which is soluble in water, and is valuable for coatings and adhesives. The final condensation product is insoluble in water, alcohol, oils, or in weak acids or alkalies, and will withstand temperatures higher than the phenol plastics. Molding is done at a pressure of 2,000 lb. per sq. in. and a temperature of 300°F., in the same manner as for other synthetic resins. The urea resins are also noted for their transparency and ability to take translucent colors. The refractive index is about the same as that of quartz, and the original Austrian urea plastic known as Pollopas was called Organic glass. It transmits ultraviolet light, but has a double refraction and is not suitable for lenses. The specific gravity of the resin is 1.44, and hardness about 3 Moh. The resins are also noted for their good adhesion to metals. They were developed in Austria and first commercialized in England. Various patents are held by the American Cyanamid Company for molding powders and for water-soluble resins used for laminated products and varnishes.

The molding powders marketed under the name of Beetle by the American Cyanamid Company are made from thiourea and formaldehyde. The specific gravity of the molded material is 1.49, tensile strength 5,000 to 7,000 lb. per sq. in., and compres, sive strength up to 26,000 lb. per sq. in. Other urea plastics are: Aldur, of the Aldur Corporation; Unite, of the Unite Corporation; Plaskon, of the Plaskon Company, Inc.; Coltrock, of the Colt's Patent Fire Arms Company. Carboloid and Marboloid are Japanese urea plastics.

Urea, known also as Carbamide, is a white crystalline substance of the composition $CO(NH_2)_2$, made by synthesis from atmospheric nitrogen. Thiourea, also known as Thiocarbamide, and as Sulphourea, is a white, crystalline substance of the composition $CH_4N_2S$. The use of thiourea improves the water resistance of the molded products.

**Valve copper.** A general name for copper casting alloys used chiefly for making "copper" valves and pipe fittings. Valve copper varies in composition, but should cast readily without cracks, checks, or porous spots, and will flow in the mold better

than copper. It may contain simply tin, zinc, or lead, or all of these. A composition used by the Parker Appliance Company, is copper, 88 per cent; tin, 4 per cent; zinc, 3 per cent; lead, 3 per cent; and nickel, 2 per cent. It has a tensile strength of 30,000 lb. per sq. in., yield point of 15,000 lb. per sq. in., and elongation of 15 per cent. A.S.T.M. brass ingot metal No. 1 is used as a high-grade Steam metal, or Valve copper. It contains 88 per cent of copper, 6.5 tin, 1.5 lead, and 4 zinc. See Brass ingot metal. The Valve bronze, or M bronze, of the U. S. Navy, contains 86 to 91 per cent of copper, 6.25 to 7.25 tin, 1.5 to 5.0 zinc, 1 to 2 lead, and up to 0.25 per cent of iron. It has a tensile strength of 34,000 lb. per sq. in. and elongation 17 per cent. See Nickel bronze.

**Vanadinite.** A minor ore of the metal lead and a source of vanadium. It is a rare mineral of secondary origin occurring in the upper oxidized parts of lead veins. It is found in Arizona and New Mexico, and in Mexico and Spain. Vanadinite has the composition $Pb_4(PbCl)(VO_4)_3$, with sometimes phosphorus and arsenic replacing part of the vanadium. It occurs in crystals and globular forms, and as incrustations. The specific gravity is 7 and the hardness is 3. The color is reddish or brown.

**Vanadium.** An elementary metal, symbol V, found widely distributed, but in commercial quantities in only a few places, chiefly Peru, Rhodesia, and Colorado. The most common ores of vanadium are carnotite, patronite, roscoelite, and vanadinite. Much of the commercial vanadium comes from Peruvian patronite and shales. Russian vanadium comes from the mineral Tyuyamunite, a vanadate of lime and uranium, mined in Turkestan. Colorado and Utah vanadium comes from carnotite, and the Arizona ore is vanadinite. Vanadium is a pale-gray metal with a silvery luster. It is brittle and has a crystalline structure. Its specific gravity is 6.02, and it melts at 3236°F. It does not oxidize in the air and is not attacked by hydrochloric or dilute sulphuric acid. It dissolves with a blue color in solutions of nitric acid. It is marketed in lump forms in grades from 80 to 95 per cent pure. Vanadium readily alloys with iron. When added to steel in small quantities, it toughens and strengthens it. It is a powerful deoxidizer, but is too expensive for this purpose alone It is

used largely in special alloy steels, being added in the form of ferrovanadium. See Vanadium steel and Chrome-vanadium steel. The metal is also alloyed with copper. Vanadium salts are used to color pottery and glass and as mordants in dyeing. Red cake, or crystalline Vanadium oxide, is a reddish-brown material, containing about 85 per cent of Vanadium pentoxide, $V_2O_5$, and 9 per cent of $Na_2O$, used as a catalyst and for making vanadium compounds. Vanadium oxide is also used to produce yellow glass; the pigment known as Vanadium-tin yellow is a mixture of vanadium pentoxide and tin oxide.

**Vanadium steel.** Vanadium was originally used in steel as a cleanser, but is now employed in small amounts, 0.15 to 0.25 per cent, especially with a small quantity of chromium, as an alloying element to make strong, tough, and hard steels. It increases the tensile strength, without lowering the ductility. It reduces grain growth and increases the fatigue-resisting qualities of steels. The steels, with 0.45 to 0.55 per cent of carbon, are used for locomotive forgings. In tool steels vanadium widens the hardening range, and by the formation of double carbides with chromium makes hard and "keen-edge" die and cutter steels. Vasco vanadium steel, of the Vanadium-Alloys Steel Company, contains 0.20 per cent vanadium with 0.80 chromium in the various carbon grades from 0.50 to 1 per cent. The higher carbon steels, for gages and rollers, have somewhat more chromium. All of these steels are classed as Chromium-vanadium steel. The Carbon-vanadium steels for forgings and castings, without chromium, have slightly higher manganese. Plain carbon Vanadium steel is regularly marketed in all standard carbon grades. It is finer grained, tougher, and keener edged than plain carbon steel. Colonial No. 7, Red star, and Elvandi, of the Vanadium Alloys Steel Company, are steels of this type. Python steel, a shock-resistant steel of the Ludlum Steel Company, has 0.20 per cent vanadium, 0.90 carbon, 0.30 manganese, and 0.25 silicon.

Vanadium steels require higher quenching temperatures than ordinary steels or nickel steels. S.A.E. 6145 steel, with 0.18 vanadium and 1 chromium, has a fine grain structure and is used largely for gears. It has a tensile strength of 116,000 to 292,000

lb. per sq. in., when heat-treated, with a Brinell hardness of 248 to 566 depending on the temperature of drawing, and an elongation of 26 to 7 per cent.

In cast vanadium steels it is usual to have from 0.18 to 0.25 per cent of vanadium with 0.35 to 0.45 per cent of carbon. Such castings have a tensile strength of about 80,000 lb. per sq. in. and an elongation of 22 per cent. A nickel-vanadium cast steel marketed by the Los Angeles Steel Casting Company under the name of Nickeladium has a tensile strength of 100,000 lb. per sq. in. with elongation of 20 per cent.

**Varnish.** A solution of a resin in drying oil, which when spread out in a thin film dries and hardens by evaporation of the volatile solvent, or by the oxidation of the oil, or both. A smooth, glossy coating is left on the surface. Varnishes do not contain pigments, and when mixed with pigments they become enamels. The most commonly used resin is ordinary rosin, and the most common drying oils are linseed and tung oils. Spirit varnishes are those in which a volatile liquid, such as alcohol or ether, is used as a solvent for the resin or oil. They dry by the evaporation of the solvent. Oleo-resinous varnishes are those in which the resin is compounded with an oxidizable oil, such as linseed oil. The gums used in varnish, such as copal, dammar, and kauri, produce hardness and gloss to the film, and the Fossil resins, such as Kauri, give greater hardness and luster to varnishes than do the natural resins. The oils, such as tung and linseed, make it elastic and durable.

Other important ingredients of varnishes are driers, such as manganese oxide, to hasten the action of the drying oil, and thinning agents, or "reducers," such as turpentine, naphtha, and benzol. Hydrated lime is added to varnishes to neutralize the acid in the resin, and to clarify and harden the varnish to prevent it from becoming sticky in warm weather. Spar varnishes are those made to withstand weather conditions. Gloss oil is a solution of hardened rosin in benzine or in turpentine with sometimes a small amount of tung oil to give a tougher film. It gives a high gloss but is not durable. Long varnishes are those containing 20 to 100 gal. of oil to 100 lb. of resin; a Short varnish is one

with less oil. The short varnishes are hard, more glossy, but not as flexible or durable.

Ordinarily, quick-drying varnish is less durable than slow-drying; hardness and gloss are not guarantees of good varnish. The quick-drying varnishes, made with a synthetic resin of the phenol type and tung oil, are very durable and are waterproof. Marine varnish is of this type. Opaque varnish, for signs, consists of synthetic resin varnish with graphite. Varnodag, of the Acheson Colloids Corporation is such a varnish, consisting of phenol-formaldehyde resin with colloidal graphite. Varnish is employed usually as a finish for fancy wood surfaces, but is also used as a protection against moisture on wood, paper, fiber, and other materials. See also Driers, Drying oils, Lacquer.

**Vegetable oils.** An important class of oils obtained from plants, used industrially as drying oils, for lubricants, in cutting oils, for dressing leather, and for many other purposes. Many of the oils find wide usage in food products. Large tracts of land are under cultivation in all parts of the world for the production of the seeds and fruits from which the oils are obtained. Linseed, cottonseed, palm, olive, and castor beans are examples of these, and the oils are obtained by crushing. The only distinction between vegetable oils and fats is a physical one, oils being fluid at ordinary temperatures. Vegetable oils can be thickened for various uses by oxidation, by blowing air through them, or they can be hydrogenated by passing hydrogen through them in the presence of a catalyst. See Hydrogenated oils, Blown oils, Castor oil, Linseed oil, Cottonseed oil, Tung oil.

**Velvet.** A closely woven silk fabric with a short pile on one side formed by carrying the warp threads over wires and then cutting open the loops. Velvet is made in a great variety of qualities and weights, and may have a cotton back in the cheaper grades, or be made in wool. True velvet is all silk, but because of the number of imitations in other materials this variety is usually designated as Silk velvet. Velvet is dyed in various colors, the depth of color shown by the pile giving it an air of richness. Its largest use is in dress goods and hangings, but it is used industrially for upholstery, fancy linings, and trim.

**Velveteen.** A variety of imitation velvet, woven of cotton. In the best grades the pile is of mercerized yarns. Velveteen is woven with two systems of filling yarns and one system of warp yarns, the pile being made with the filling yarns instead of the warp yarns as in velvet. It belongs to the class of Fustians which includes also Moleskin and Corduroy. Velveteen is used industrially for linings for jewelry and silverware boxes, shoe uppers, artificial flowers, and covering material.

**Vermiculite.** A foliated mineral employed in making plasters and boards for heat, cold, and sound insulation, as a filler in caulking compounds, and for plastic mortars and refractory concrete. The mineral is an alteration product of biotite and other micas, and is found in Colorado and Montana, and in the Transvaal. It occurs in crystalline plates, specific gravity 2.3 and hardness 1.5, measuring sometimes as much as 9 in. across and 6 in. in thickness. The color is yellowish to brown. Upon calcination at 1750°F. vermiculite expands at right angles to the cleavage into a fluffy mass, the volume increasing as much as 16 times, and the color changing to a silvery or golden hue. It is ground into pellet form. Plaster made with 60 per cent of vermiculite, 30 of plaster of paris, and 10 of asbestos will withstand red heat without disintegrating. The corklike pellets used for insulating fill in house walls are called Mica pellets. Zonolite, of the Zonolite Company, is an exfoliated vermiculite. A sound-absorbing building tile marketed by Johns-Manville under the name of Rockoustile is made of exfoliated mica. An expanded vermiculite of extremely fine mesh, under the name of Mikolite, of the Mikolite Company, is used as an extender in aluminum paint and in heavy lubricating oils.

**Vermilion red.** One of the oldest paint pigments. It is a brilliant red powder of the composition HgS, known chemically as Red mercury sulphide. The specific gravity is about 8.10. It is insoluble in water. Vermilion red is expensive, more than 85 per cent of its weight being mercury, and is consequently often mixed with red lead, red ochre, or red iron oxide, or is replaced by Antimony red. It is made by heating mercury and sulphur together and grinding the product.

**Victor metal.** A name given to a nickel-silver alloy containing 50 per cent of copper, 35 of zinc, and 15 of nickel. It casts well, machines easily, and is used for cast fittings. It is a white metal with a yellow shade. The alloy is very resistant to corrosion. See Nickel-silver.

**Vine black.** The charred remains of partly burned vines or twigs, ground very fine and used as a pigment, especially for inks. The name is now also applied to the black made from fruit pits and nut shells. See Charcoal.

**Vinyl resins.** A group of products varying from liquid to hard solids, made by the polymerization of ethylene derivatives, employed for finishes, coatings, and molding resins. The simplest are the poly-esters of vinyl alcohol, one of the most common being made by the reaction of vinyl chloride and vinyl acetate. Polyvinyl alcohol is a colorless, odorless, tasteless powder which on drying from solutions forms a colorless and tough film. It is used for adhesives, paper, and fabric coatings, or can be molded. It is resistant to acids and alkalies. Vinyl acetate is a water-white mobile liquid with boiling point of about 72°C. and specific gravity 0.934, usually shipped with a copper salt to prevent spontaneous polymerization. The composition is $CH_3\cdot COO\cdot CH:CH_2$. It is polymerized into a resin by the action of heat, light, or oxides. The higher the polymerization of the resin, the higher the softening point of the resin. Polyvinyl acetate resins are colorless, odorless, and permanently thermoplastic. They are stable to light, transparent to ultraviolet light, have high dielectric strength, and are hard and tough. They are valued for lacquers because of their high adhesion, durability, and ease of compounding with gums and resins. Vinylite and Vinyloid are trade names of the Carbide and Carbon Chemicals Corporation for vinyl-acetate resins. They are molded with heat and pressure like other synthetic resins, and are compounded with wood flour, asbestos, mica, and other fillers. The clear resins are light in color. Vinyon, of the same company, is a polyvinyl acetal resin fiber which is produced in various grades as fine as natural silk. It is waterproof, more elastic than natural silk, and nearly as strong. Since it is resistant to strong acids and

alkalies it is made into filter cloth. It is produced by the copolymerization of vinyl chloride and vinyl acetate. Victron, of the Naugatuck Chemical Company, is a vinylite resin. Mowilith is a German vinylite resin. Gelva, of the Shawinigan Products Corporation, is a polyvinyl acetate resin used for lacquers. Formvar, of the Carbide & Carbon Chemicals Corporation, and Formex, of the General Electric Company, are vinyl-formaldehyde resins used for such purposes as coating insulated wire. Butacite, of E. I. du Pont de Nemours & Co., Inc., is a polyvinyl butyral resin.

**Vitriol.** A commercial name for sulphuric acid. It is also called Oil of vitriol. See Sulphuric acid. Green vitriol is the common name for ferrous sulphate. Blue vitriol is a name for copper sulphate. White vitriol is zinc sulphate.

**Vulcanized fiber.** A wood, paper, or other cellulose fiberboard impregnated with a gelatinizing medium. It is not vulcanized in the same sense that rubber is vulcanized. It is made by various processes, and the medium may be sulphuric acid, zinc chloride solution, or cupro-ammonium solution. It may also be made by impregnating the cellulose fiber with a phenol-furfural resin dissolved in alcohol or other solvent. After dipping in the solution the fiber is washed to remove excess alcohol, and then dipped in a zinc chloride solution which hydrolizes it, and it is then washed free of the chloride, dried, and rolled. The original vulcanized fiber, patented in 1899 and called Cellulith, was sulphite wood pulp molded into sheets or formed parts. The modern fiber in the hard grades is a tough, resilient, hornlike material in standard gray, red, and black colors. Soft flexible grades are made for washers and gaskets.

Another type of material, called Maizolith, developed by the National Bureau of Standards, is a hard, dense product made by cooking cornstalks or corncobs with caustic soda, washing out the residue, beating, and compressing. It has a tensile strength of 8,000 lb. per sq. in., hardness of 15 to 30 Brinell, is resistant to oils, is a good insulator, and resembles vulcanized fiber.

The "Hard vulcanized fiber," produced by the Spaulding Fibre Company, Inc., is made from cotton rags softened and

gelatinized in a zinc chloride solution and built up in layers. The specific gravity is from 1.1 to 1.4, the heavier thicknesses being the lightest and the softest. The shearing strength is 10,000 to 15,000 lb. per sq. in. and compressive strength 30,000 lb. per sq. in. The dielectric strength is from 275 to 375 volts per mil. Sheets as thin as 0.004 in. are produced. The Diamond fiber marketed by the Continental-Diamond Fibre Company, is made in various grades with compressive strengths up to 40,000 lb. per sq. in. "Bone quality" is a dense material with a specific gravity of 1.40, made in thicknesses from 1/8 to 1/2 in., with high machining properties. The "Commercial quality" is made in thicknesses from 0.004 to 2 in. The thin paper sheets are used for armature insulation. Codite is the trade name of this company for a hard, tough, vulcanized fiber tubing with dielectric strength up to 710 volts per mil. Cellulak is another tubing of the same company made of kraft paper coated with resin and laminated under heat and pressure. Flexible fiber is a grade of vulcanized fiber made to retain sufficient moisture to keep it soft. Vulcanized fibers are used for electrical insulation, gaskets, gears, rollers, handles, and for such articles as trunks, boxes, and novelties. For electrical insulation it has the disadvantage that it absorbs moisture in damp places unless impregnated with insoluble resins. The higher grades of vulcanized fibers, and those for electrical work, are all now of the insoluble type. Victorite, of the Victor Mfg. & Gasket Company, is an impregnated manila-rope paper, used for gaskets. Fish paper, for electrical use, may be vulcanized fiber in thicknesses from 0.005 to 1/16 in. The 0.005-in. paper will withstand 1,500 volts. Protectite, of the National Vulcanized Fibre Company, is a thin white vulcanized fiber sheet used for backing rubber shoe soles. Shoe fiber is sheet material in leather color used for reinforcements in shoes. It is very resilient, but can be cut with dies and nailed. See Laminated plastics.

**Vulcanized oils.** Vegetable oils vulcanized with sulphur and used for compounding with rubber for rubber goods, or as a rubber substitute in erasers. Castor oil, corn oil, and soybean oil are used. Vulcanized oil is a white to brown, spongy, and odorless cake, or sticky plastic, with specific gravity of 1.04. The

material is known as Factice in the rubber industry. Factice cake is solidified vulcanized oils, cut in slab form for compounding with rubber. Factice is not a mere adulterant of rubber, but may be used to give certain desirable characteristics such as softness or plasticity. The Brown factice of the Stamford Rubber Supply Company is vulcanized oil; the Black factice has mineral bitumen added. Neophax is the trade name of this company for brown factice, and Amberex is the name for light-tan colored factice. Mineral rubber is a name sometimes applied to vulcanized oils mixed with bitumens, especially gilsonite, but this term is also applied to petroleum asphalt when used in rubber compounding for such uses as shoe soles.

**Vulcanized rubber.** Crude rubber, as obtained by precipitation or coagulation from the latex of the rubber tree, does not have the elastic or other properties of commercial rubber. To obtain these it is purified, and "vulcanized" by heating together with sulphur at a temperature of about 140°C. From 3 to 35 per cent of sulphur is used, depending upon the class of rubber desired. A part of the sulphur is actually taken up by the molecule of the rubber, forming a chemical combination and not acting as a filler. The process was invented in 1839 by Charles Goodyear. The ordinary soft, elastic rubbers contain from 3 to 6 per cent of sulphur. All rubber is vulcanized, but when vulcanized rubber is designated in the trade it usually refers to the hard rubbers, or Ebonite, made with about 30 per cent of sulphur. These are very hard and brittle, and are used for molded articles, especially for electrical parts. Hard rubber for molded parts and as linings for acid-resistant pipes and pumps may contain up to 50 per cent of sulphur. The tensile strength is from 1,500 to 10,000 lb. per sq. in., compressive strength 3,000 to 20,000 lb. per sq. in., and specific gravity about 1.15. The dielectric strength is 1,000 to 1,200 volts per mil. It resists temperatures up to 200°F. and is not absorbent. See also Rubber.

Vultex, of the Vultex Chemical Company, is a water solution of prevulcanized rubber in various types of cure. Evaporation of the water produces a vulcanized rubber product. Vultex is marketed in liquid or paste forms, and is used for coatings and

adhesives. Vulcanized rubber containing graphite is used for machine bearings. Parock, producted by Raybestos-Manhattan, Inc., is a bearing material for oilless bearings, containing about 80 per cent of graphite bonded with vulcanized rubber. The crushing strength is up to 8,000 lb. per sq. in.; the coefficient of friction is 0.1 to 0.13 dry, and 0.05 to 0.08 wet.

**Walnut.** A hardwood from the tree *Juglans regia*, native to Europe. The wood is firm, with a fine to coarse, open grain, and a lustrous surface. The weight is about 45 lb. per cu. ft. The color is dark brown to black, and it takes a beautiful polish. Walnut has great strength, toughness, and elasticity. It also has great uniformity of texture and does not split easily. It is particularly adapted for carving. Walnut is valued as a cabinet wood, for fine furniture, and for gun stocks. Black walnut is from the tree *J. nigra*, of North America. The color is darker, and it has a more uniform color than European walnut. It has the same general characteristics and uses as European walnut. It has a specific gravity, kiln-dried, of 0.56, a shearing strength parallel to the grain of 1,000 lb. per sq. in., and a compressive strength perpendicular to the grain of 1,730 lb. per sq. in. Butternut, from the tree *J. cinerea*, resembles closely the wood of the black walnut except its color, which is yellowish gray. The supply of this wood is limited. Satin walnut is an English name for the wood of the American red gum tree, *Liquidambar styraciflua*, of the Southern States. See Gum. Walnut oil is a yellowish oil obtained by pressing the nut kernels. It is a good drying oil and is used especially for artists' paints. The specific gravity is 0.919 to 0.929 and iodine value is 148. It is soluble in alcohol. The oil from the candle-nut is also called walnut oil.

**Walrus hide.** The skin of the walrus, a marine mammal, *Odontobaenus rosmarus*, and *O. obesus*, native to the North Atlantic and Pacific Oceans. The animals sometimes have a length of 16 ft., and a weight up to 2,000 lb., and the hide is obtainable in large pieces. They congregate in herds on the icebergs of the North. The skin is tanned and makes a leather with a beautiful natural grain. It is also very tough and was formerly much used for coach traces. It is now employed where a tough and orna-

mental leather is required. Walrus leather is imitated with embossed heavy sheepskin, and the leather is used for such things as bags and coverings.

**Waste.** The waste cotton threads and yarns from the cotton mills, used in manufacturing plants for wiping machinery. The best grades are usually all white, of clean soft threads without sizing or sweepings, and composed of yarns more than 10 in. long. Various other grades are available, composed of mixed white and colored threads, and the poorest having short threads and foreign matter. Good cotton waste is very absorbent and makes a good wiping material in machine shops. It can be scoured and used over and over. Comber waste consists of the lengths of fiber up to 1 in., and is not sold with the waste from yarns, but is sent to mills producing cheap fabrics.

**Water glass.** Also called Soluble glass. A soluble silicate of sodium known chemically as Sodium meta-silicate or Sodium silicate, and having the composition $Na_2SiO_3$ or $NaSiO_3{\cdot}9H_2O$. When solid it is glassy in appearance and dissolves in hot water. It melts at 1018°C. It is obtained by melting sodium carbonate with silica, or by melting sand, charcoal, and soda. The fused product is ground and dissolved in water by long boiling. Potassium silicate is made in the same way, or a double soluble glass is made by using both sodium and potassium carbonates. Potassium silicate is more soluble than sodium silicate. Water glass is marketed as a viscous liquid or in powder form. It is used as a protection for wood and porous stone, as a fixing agent for pigments, for cementing stoneware, for lute cements for such uses as sealing electric-light bulbs, for waterproofing walls, greaseproofing paper containers, and as a filler for soaps. It increases the cleansing power of soaps but irritates the skin. Mixed with whiting it is used as a strong cement for grinding wheels. Sodium meta-silicate marketed by the Philadelphia Quartz Company as a cleaner of metals is a crystalline powder. Hot solutions of this salt in water are caustic and will clean grease from metals. Penchlor, of the Pennsylvania Salt Manufacturing Company, is an Acid-proof cement made by mixing cement powder with a sodium silicate solution. It is used for

lining chemical tanks and drains. Aquagel, of the Silica Products Company, is a hydrous silicate of alumina, used in the same manner for waterproofing concrete. See also Ethyl silicate.

**Water repellants.** Chemicals used for treating textiles, leather, and paper such as washable wallpaper, to make them resistant to wetting by water. They are different from waterproofing materials in that they are used where it is not desirable to make the material completely waterproof, but to permit the leather or fabric to "breathe." Water repellants must not form acids that would destroy the material, and they must set the dyes rather than cause them to bleed on washing. They usually consist of a mineral salt over which a wax emulsion is placed; the treatment may be a one-bath process, or be by two separate treatments. Aluminum acetate is one of the most common materials for this purpose. Basic aluminum acetate is a white, amorphous powder of the composition $Al(OH)(OOC{\cdot}CH_3)_2$. It is only slightly soluble in water but is soluble in mineral acids. See also Aluminum palmitate and Mineral soaps. Wetting agents are materials, usually liquids, used to aid in mixing pigments or fillers in solution for paints, adhesives, or other products. Many mineral powders will not wet and go into solution easily with oils or water and require the addition of an agent with a mordant action. Pine oil is a common wetting agent.

**Water softeners.** Chemical compounds used for converting the soluble scale-forming solids in boiler feed water into insoluble forms. In the latter condition they are then removed by settling or filtration. The "hardness" of water is due chiefly to the presence of carbonates, bicarbonates, and sulphates of calcium and magnesium. Temporary hard waters are those that can be softened by boiling; permanent hard waters are those that require chemicals to change their condition. Sodium hydroxide is used to precipitate magnesium sulphate. Caustic lime is employed to precipitate bicarbonate of magnesium, and sodium aluminate is used as an accelerator. Alum is used to precipitate mud and other impurities. Water softeners may consist of mixtures of lime, soda ash, and sodium aluminate, the three acting together. Barium carbonate may also be used as a softener. The

water is treated with the chemicals before it is run into the boiler. See also Boiler compounds.

**Wax.** A general name for a variety of substances of animal and vegetable origin, which are esters of the fatty acids, but differ from fats chiefly in the fact that glycerin is not separated out on saponification. They are usually harder than fats, but when used alone do not mold so well. The most familiar wax is beeswax, from the honeybee, but commercial beeswax is usually greatly mixed or adulterated. Vegetable waxes include Japan wax, candelilla, and carnauba wax. Mineral waxes include paraffin wax from petroleum, ozokerite, ceresin, montan wax. These differ from the true waxes in chemical composition and are mixtures of saturated hydrocarbons. Animal waxes are beeswax, spermaceti, degras. Waxes are employed in polishes, phonograph records, leather dressings, sizings, waterproofing for paper, candles, and in varnishes. They are softer and have lower melting points than resins, are soluble in mineral spirits and in alcohol, and insoluble in water. See Carnauba wax, Beeswax, Paraffin.

**Wear-resistant steel.** Many types of steel have wear-resistant properties, but the term usually refers to high-carbon, high-alloy steels used for press dies subject to abrasion and for wear-resistant castings. They are generally cast and ground to shape. They are mostly sold under trade names for specific purposes. Adamite is the trade name of the Mackintosh-Hemphill Company for a high-carbon, nickel-chromium-iron alloy used for drawing and forming dies. The Brinell hardness ranges from 186 to 477 as cast, with tensile strengths up to 125,000 lb. per sq. in. The various grades contain from 0.50 to 1.50 chromium, with half this amount of nickel in each case, carbon from 1.25 to 3.50 per cent, and silicon from 0.50 to 2.0 per cent. The softest grades can be machined and then hardened, but the hard grades are finished by grinding. Castaloy, of the Detroit Alloy Steel Company, is a high-carbon, high-chromium steel for automobile fender dies and wear-resistant castings. Martin steel, of this company, is an air-hardening steel containing 12 to 14 per cent of chromium, 0.85 to 1.25 molybdenum, 0.35 vanadium, 0.80 cobalt, and 1.40 to 1.60 carbon. It is highly resistant to abrasion.

Dasco is a general trade name for steels of this company. Carbomang is another cast-to-shape steel of the same company containing 1 to 1.25 per cent of manganese, 0.45 chromium, 0.50 tungsten, 1 carbon. It can be cast to intricate shapes and is oil hardening. Cobaltchrom is a nondeforming, wear-resistant cast steel for cutting and stamping dies. It contains 12 to 14 per cent of chromium, 0.80 cobalt, and 1.5 carbon. Krokoloy is a die steel of the 14 per cent chromium type containing higher cobalt, and is air hardening. Kinite, of the Kinite Corporation, for blanking and forming dies, and for cams and cutters, contains 12.5 to 14.5 per cent of chromium, 1.5 carbon, 1.10 molybdenum, 0.70 cobalt, 0.55 silicon, 0.50 manganese, and 0.40 nickel. It has high compressive strength. Cristite, of the Commercial Alloys Company, contains 10 per cent of chromium, 17 tungsten, 3.5 carbon, 2.5 molybdenum, and is notable for corrosion and acid resistance. Circle L4 steel, of the Lebanon Steel Foundry, used for cams and rolls, contains 1.25 to 2.0 per cent of chromium, 1 to 1.5 manganese, 1 molybdenum, 0.12 vanadium, and 0.8 carbon.

**Weld.** The dried plant, *Reseda luteola*, cultivated in Europe and used as a dyestuff. The coloring matter is allied to morin, and produces an extremely bright yellow color with an alum mordant. With indigo it produces shades of green.

**Welding rods.** A general name applied to metal rods and wire used for either electric or gas welding, or for building up surfaces, or hard-facing surfaces. Nonferrous rods used for welding bronzes are usually referred to as Brazing rods as the metal to be welded is not fused when using them. Welding rods may be of standard metals such as naval brass for cast-iron welding, but are more usually special alloys, coated with a fluxing material or uncoated, and are normally in diameters from $\frac{3}{32}$ to $\frac{1}{4}$ in. Brass rods usually contain some silicon to lessen the vaporization by forming a film. Sifbronze, an English brass welding rod, contains some ferromanganese and tin, and welds on cast iron have a tensile strength of 32 tons per sq. in. Low-carbon steel rods for welding cast iron and steel contain less than 0.18 per cent of carbon. High-carbon rods produce a hard deposit that requires annealing, but these are also used for producing a hard

filler. High-carbon rods, with 0.85 to 1.10 per cent of carbon, will give deposits with initial hardness of 575 Brinell, whereas high-manganese rod deposits will be below 200 Brinell but will work-harden to above 500 Brinell. Stainless steel rods are marketed in various compositions. Stainless C, of the Lincoln Electric Company, is an 18–8 type of stainless steel containing also 3.5 per cent of molybdenum. Compositions of standard welding rods follow the specifications of the American Welding Society. Amsco welding rod, for pointing dipper teeth and for hard-facing tools, is a high-manganese steel of the American Manganese Steel Company. It is marketed in grades giving hardness from 500 to 700 Brinell. Stoodite is a high-manganese steel in the form of rods marketed by the Stoody Company for hard facing. Elkonite, of the P. R. Mallory Company, is the name of a group of welding alloys made especially for welding machines. They are, in general, sintered tungsten or molybdenum carbides combined with copper or silver, and are electrodes for spot welding rather than welding rods. They are durable and wear-resistant in service. Hascrome, of the Haynes Stellite Company, is a self-hardening chromium-manganese-iron alloy in the form of welding rods for building up worn parts or hard facing. The hardness of the deposit is regulated by the flame and the cooling, and ranges from 250 to 500 Brinell. Cromansil, of the Metal & Thermit Corporation, has 1 per cent of nickel, 0.30 chromium, and 0.80 molybdenum. The tensile strength of the weld is 90,000 lb. per sq. in. Cor-ten is a chrome-copper steel rod for welding stainless steels. Murex is a 13 per cent manganese steel rod with 1 per cent carbon and 0.85 nickel. See also Timang and Welding flux.

**Western red cedar.** The wood of the tree *Thuya plicata*, also known as Arbor vitae, Shinglewood, and Pacific red cedar. The tree grows in cool, humid coast regions from Alaska to northern California, and the wood is widely used for shingles, poles, and tanks. It is light in weight, soft, and weak, with a straight coarse grain, but is durable. The sapwood is white and the heartwood reddish. The tree grows to great size, reaching to 200 ft. in height and 16 ft. in diameter at the age of 1,000 yrs. The stand is

estimated at 53 billion bd. ft. Northern white cedar is the wood of the tree *T. occidentalis*, of the Northeastern United States. It is also called White cedar, Arbor vitae, or simply Cedar. The wood is soft, brittle, weak, but very durable. It is used for shingles, poles, posts, and lumber for small boats. The sapwood is white and the heartwood light brown.

**Whalebone.** The elastic, hornlike strips in the upper jaw of the Greenland whale, *Balaena mysticetus*, and some other species. The strips are generally from 8 to 10 ft. long and number about 600. Whalebone is light in weight, very flexible, elastic, tough, and durable. It is easily split and is carved easily when softened in hot water. Whalebone has a variety of uses in making whips and in articles that require flexibility. Baleen is a trade name for strips of whalebone used for whips, and for products where great flexibility and elasticity are required.

**Whale oil.** An oil extracted by boiling and steaming the blubber of several species of whale, *Balaena*, that are found chiefly in the cold waters of the extreme North and South. The whale industry now centers about South Georgia. Whale oil is marketed according to grade, which depends upon its color and keeping qualities. The latter in turn depends largely upon its proper cooking at extraction. No. 0 and No. 1 grades are fine pale-yellow oils, No. 2 is amber, No. 3 is pale brown, and No. 4 is the darkest oil. The oils contain oleic, stearic, palmitic, and other acids. The specific gravity is about 0.925, saponification value 185, and iodine value 120. The oil of the sperm whale has high content of spermaceti, and the iodine and saponification values are lower than whale oil. Whale oils of the lower grades are used for quenching baths for heat-treating steels, and also in lubricating oils. The best oils are hydrogenated for use in soaps and candles. Sperm oils are used for lubricating. See Sperm oil, Jaw oil and Blackfish oil.

**Whetstone.** Stones of regular fine grains composed largely of chalcedony silica, often with minute garnet and rutile crystals. They are used as fine abrasive stones for the final sharpening of edge tools. Whetstones are sometimes selected, fine sandstones

from the grindstone quarries. The chocolate whetstone from New Hampshire is mica schist. The finest whetstones are called oilstones. See Oilstone. A fine-grained Honestone, known as Coticule, comes from Belgium, and is used for sharpening fine-edged tools. It is compact, yellow in color, and contains minute crystals of yellow manganese garnet, with also potash mica and tourmaline. Coticule is often cut double with the blue-gray Phyllite rock adhering to and supporting it. Scythestones are made from Ohio and Indiana sandstones, and from the schist of Vermont. Rubbing stones are fine-grained Indiana sandstones.

**White brass.** A bearing metal which is actually outside of the range of the brasses, bronzes, or babbitt metals. It is used in various grades, the specification adopted by S.A.E. being tin, 65 per cent; zinc, 28 to 30 per cent; and copper, 3 to 6 per cent. It is used for automobile bearings, and is close-grained, hard, and tough. It also casts well. An entirely different alloy is known under the name of white brass in the cheap jewelry and novelty trade. It has no tin, small proportions of copper, and the remainder zinc. It is a high-zinc brass, and varies in color from silvery white to yellow depending upon the copper content. An old alloy formerly used for casting buttons, known as Birmingham platina, or Platina, contained 75 per cent of zinc and 25 copper. It has a white color but is very brittle. A yellowish metal, known as Bath metal, once widely used for casting buttons, candlesticks, and other articles, was a brass containing 55 per cent of copper and 45 zinc. White nickel brass is a grade of nickel silver. The White brass used for castings where a white color is desired may contain up to 30 per cent of nickel. The 60–20–20 alloy is used for white plaque castings for buildings. See Statuary bronze. The high-nickel brasses do not cast well unless they also contain lead. Those with 15 to 20 per cent of nickel and 2 lead are used for casting hardware and valves. See Nickel brass. White nickel alloy is a cupro-nickel containing some aluminum. White copper is a name sometimes used for cupro-nickel or nickel brass.

**White cement.** Portland cement made from pure calcite limestones and white clays, notably the raw materials of eastern

Pennsylvania and of France. The physical properties are much the same as those of gray portland cement, but the white cements are usually ground finer, and are employed for plastering, facing, and for blocks. A heat-resistant and insulating concrete is made from a white cement produced from a mixture of Greek bauxite and lime.

**White gold.** The name of a class of jewelers' white alloys used as substitutes for platinum. The name gives no idea of the relative value of the different grades, which vary widely. Gold and platinum may be alloyed together to make a white gold, but the usual alloys consist of from 20 to 50 per cent of nickel, with the balance gold. Nickel and zinc with gold may also be used for white golds. The best commercial grades of white gold are made by melting the gold with a white alloy prepared for the purpose. This alloy contains nickel, silver, palladium, and zinc. The 14-carat white gold contains 14 parts of pure gold and 10 white alloy. A superior class of white gold is made of 90 per cent of gold and 10 of palladium. High-strength white gold contains copper, nickel, and zinc, with the gold. Such an alloy, containing 37.5 per cent of gold, 28 of copper, 17.5 of nickel, and 17 of zinc, when "aged" by heat-treatment, has a tensile strength of about 100,000 lb. per sq. in. and an elongation of 35 per cent in 2 in. It is used for making jewelry, has a fine, white color, and is easily worked into intricate shapes. White-gold solder is made in many grades containing up to 12 per cent of nickel, up to 15 zinc, with usually also copper and silver, and from 30 to 80 per cent of gold. The melting points of eight grades marketed by Handy & Harman are from 695 to 845°C.

**White lead.** The common name of Basic lead carbonate, the oldest and most important paint pigment, and also used in putty and ceramics. White lead is used in almost all mixed paints. It is a white, poisonous amorphous powder of the composition $2PbCO_3 \cdot Pb(OH)_2$. It is insoluble in water, and decomposes on heating. The specific gravity is 6.7. It is made from metallic lead, and is marketed dry, or mixed with linseed oil and turpentine in paste form. Lead carbonate, $PbCO_3$, is used as a pigment in the same way as the basic compound, but it discolors

more easily. Basic lead sulphate, called Sublimed white lead, makes a fine white pigment. Commercial sublimed white lead contains 75 per cent of lead sulphate, 20 of lead oxide, and 5 of zinc oxide. Commercial white lead may be mixed or adulterated with lithopone, magnesium oxide, antimony oxide, witherite, or other materials. See also Blue lead.

**White metals.** Although a great variety of combinations can be made with numerous metals to produce white, or silvery, alloys, the name usually refers to the lead-antimony-tin alloys employed for machine bearings, packings, and linings, to the low-melting-point alloys used for toys, ornaments, and fusible metals, and to the type metals. See Babbitt, and Antimonial lead. A number of white metals are specified by the A.S.T.M. for bearing use. These vary in the wide range from 2 to 91 per cent of tin, 4.5 to 15 antimony, up to 90 per cent of lead, and up to 8 of copper. The alloy containing 75 per cent of tin, 12 antimony, 10 lead, and 3 copper, melts at 184°C., is poured at about 375°C., has an ultimate compressive strength of 16,150 lb. per sq. in. and a Brinell hardness of 24. The alloy containing 10 per cent tin, 15 antimony, and 75 lead melts at 240°C., has a compressive strength of 15,650 lb. per sq. in. and a Brinell hardness of 22. The first of these two alloys contains copper-tin crystals; the second contains tin-antimony crystals. A white bearing metal produced by the American Smelting & Refining Company, under the name of Asarcoloy, is composed of cadmium with 1.3 per cent of nickel. It contains $NiCd_7$ crystals, and is harder and has higher compressive strength than babbitt and a low coefficient of friction. It melts at 604°F. Thermit metal, produced by the Goldschmidt Aktiengesellschaft, is a lead-base metal containing 0.7 to 1.5 per cent of nickel and cadmium to hold up the lead in solution. The lead content is as high as 78 per cent. The compressive strength is 25,000 lb. per sq. in. and the hardness 29 Brinell. One of the oldest of the American antifriction lead-base bearing metals is Magnolia metal, marketed by the Magnolia Metal Company. It contains as high as 80 per cent of lead, with considerable antimony, and in some grades tin, phosphorus, arsenic, or other elements.

Various high-tin, or reverse, bronzes have been used as corrosion-resistant metals, especially before the advent of the chromium, nickel, and aluminum alloys for this purpose. Trabuk was a corrosion-resistant high-tin bronze with about 5 per cent of nickel. Fahry's alloy was a Reverse bronze containing 90 per cent tin and 10 copper, used as a bearing metal. The bearing alloy known in England as Motor bronze is a babbitt with about double the amount of copper of a standard babbitt. One analysis gives tin, 84 per cent; antimony 7.5; copper, 7.5; and bismuth 1 per cent. An old alloy, used in India for utensils, and known as Bidery metal, contained 31 parts of zinc, 2 lead, and 2 copper, fluxed with resins. It was finished with a velvety-black color by treating with a solution of copper sulphate. Fahlum metal, used for stage jewelry, contains 40 per cent tin and 60 lead: When faceted, it makes highly reflective brilliants. See also Zinc-base alloys, Expansive metals, White brass, Argentine metal, Pro-platinum. An alloy used for dies for casting plastics contains 48 per cent of bismuth, 28.5 lead, 14.5 tin, and 9 antimony. It is nonshrinking and has good resistance to compression.

**Willemite.** An ore of the metal zinc. It is zinc ortho-silicate, $Zn_2SiO_4$, containing theoretically 58.6 per cent of zinc. Manganese often replaces part of the zinc, and it is then called Troostite. Its structure is massive or granular, and it has a vitreous luster. The color is white, yellowish green, or blue when pure but with manganese it becomes apple-green, red, or brown. It may be transparent or opaque. The hardness is about 5.5, and the specific gravity is about 4. Willemite is found in various places in the United States.

**Willow.** The wood of the trees *Salix coerulea* and *S. alba*, native to Europe, but grown in many other places. It is best known as a material for cricket bats made in England. The American willows are known as Black willow, from the tree *S. nigra*, and Western black willow from the tree *S. lasiandra*. The wood is also employed for making artificial limbs, and for articles where toughness and nonshrinking qualities are valued. The wood is brownish yellow in color, has a fine, open grain, and weighs about 30 lb. per cu. ft. It is of the approximate hardness of

cherry and birch. Japanese willow is from the tree *S. urbaniana*. It has a closer and finer texture, and has a browner color. Black willow has a maximum crushing strength parallel to the grain of about 1,500 lb. per sq. in.

**Wire cloth.** Stiff fabrics made of fine wire woven with plain loose weave, used for screens to protect windows, for guards, and for sieves and strainers. Steel and iron wire may be used, either plain, painted, galvanized, or rust-proofed, or various nonferrous metal wires are employed. It is usually put up in rolls of 100 ft., in widths from 18 in. to 48 in. Screen cloth is usually 12, 14, 16 or 18 mesh; wire cloth in copper, brass, or Monel metal is made regularly in meshes from 4 to 100. The size of wire usually varies from 0.009 to 0.065 in. in diameter. Wire cloth for fine filtering is made in very fine meshes. "Mesh" indicates the number of openings per inch, and has no reference to the diameter of wire. A 200-mesh cloth has 200 openings each way on a square inch, or 40,000 openings per sq. in. Wire cloth as fine as 400 mesh, or 160,000 openings per sq. in., is made by the Newark Wire Cloth Company by wedge-shaped weaving, although 250 wires of the size of 0.004 in. when placed parallel and in contact will fill the space of 1 in. Very fine mesh wire cloth must be woven at an angle since the globular nature of most liquids will not permit passage of the liquid through microscopic square openings. High-manganese steel wire is used for rock screens. See Timang.

**Wire glass.** A variety of glass used in building construction for windows, doors, floors, and skylights, and having woven wire mesh embedded in the center of the plate. It does not splinter or fly apart like common glass when subjected to fire or shock, and has higher strength than common glass. It is made in standard thicknesses from ⅛ to ⅜ in., and in plates 60 by 110 in. and 61 by 140 in. Underwriters' specifications call for a minimum thickness of ¼ in. Wire glass is made with plain, rough, or polished surfaces, or with ribbed or cobweb surface on one side for diffusing the light and for decorative purposes. It is also obtainable in corrugated sheets, usually 27¾ in. wide. Wire glass ¼ in. thick weighs 2.25 lb. per sq. ft.

**Wolframite.** The chief ore of the metal tungsten. Its composition is $(FeMn)WO_3$. When the manganese tungstate is low, the ore is called Ferberite; when the iron tungstate is low, it is called Hübnerite. The ore is concentrated by gravity methods to a concentrate containing 60 to 65 per cent of tungstic oxide, $WO_3$. To extract pure $WO_3$ from the concentrate it is fused with sodium carbonate, $NaCO_3$, to form sodium tungstate, $NaWO_3$, which is dissolved in water. When an acid is added to the solution, the $WO_3$ precipitates out as a yellow powder. The metallic tungsten is obtained by reducing, and is then pressed into bars and sintered. Wolframite occurs usually bladed or columnar in form. It has a specific gravity of 7.2 to 7.5 and a hardness of 5. It has a black color, and a submetallic luster. It is found in the Mountain states, Alaska, China, and Argentina, but is also widely distributed in various parts of the world in small quantities. Chinese wolfram concentrates contain 65 per cent of tungstic oxide; the Arizona concentrates contain an average of 67 per cent. California and Nevada concentrates are scheelite containing from 60 to 67 per cent of tungstic oxide. See Tungsten.

**Wollaston wire.** Any wire made by the Wollaston process of fine wire drawing. It consists in inserting a length of bare drawn wire into a close-fitting tube of another metal, the tube and core then being treated as a single rod and drawn through dies down to the required size. The outside jacket of metal is then dissolved away by an acid which does not affect the core metal. Platinum wire as fine as 0.00005 in. in diameter is made commercially by this method, and gold wire as fine as 0.00001 in. in diameter is also drawn. Wires of this fineness are employed only in instruments. They are marketed as composite wires, the user dissolving off the jacket.

**Wood.** A general name applied to the cut material derived from trees. Timber, in general, refers to standing trees, while Lumber is the sawed wood used for construction purposes. In construction work the word Timber is often applied to large pieces of lumber used as beams. Wood is an organic chemical compound composed of approximately 49 per cent carbon, 44 oxygen, 6 hydrogen, and 1 ash. It is largely cellulose and lignin.

Wood is produced in most trees by a progressive growth from the outside. In the spring when sap flows rapidly a rapid formation of large cells takes place, followed by a slower growth of hard and close cells in the summer. In some woods, such as oak, there is a considerable difference in quality and appearance between the spring and summer woods. In some long-lived trees, such as Douglas fir, there is a difference in the strength between the outside wood with narrow rings and the wide-ringed wood of the interior or young fast-growing trees. Heartwood is the dark center of the tree which has become set, and through which the sap has ceased to flow. Sapwood is the outer, live wood of the tree; unless treated, it has low decay resistance. The grain of sawed lumber results from sawing across the annual growth rings and can be varied to produce different grains.

Wood is seasoned either by exposing to the air to dry, or by kiln drying. The former method is considered to give superior quality, but requires more time, is expensive, and is indefinite. Numerous tests made at the U. S. Forest Products Laboratory did not reveal any superiority in air-dried wood when kiln drying was well done. Seasoned wood, when dry, is several times stronger than unseasoned wood. The safe working stresses of the common construction woods in compression perpendicular to the grain are 900 to 1,300 lb. per sq. in. In the United States the distinction between Hardwoods and Softwoods is made arbitrarily by the class of tree, the evergreens being "softwoods" without reference to the actual hardness of the wood. Wood decays easily when subject to alternate wetting and drying, unless treated with creosote or zinc chloride. A standard table of relative hardness of woods is given in the Appendix.

Lumber is graded from "A Select," which is practically free from defects, to "D Select," which contains more defects than other selects but none detracting from a finished appearance. The common grades run from "No. 1 Common," with only few and tight knots, to "No. 5 Common," with coarse defects such as decay, holes, and wane. The term Log designates the tree trunk with the branches removed. Balk is a roughly-squared log; Plank is a piece cut to rectangular section 11 in. wide; Deal is one 9 in. wide; and Batten is one 7 in. wide. Board is a thin piece of

any width less than 2 in. thick. Flitch is half a balk cut in two lengthwise. Scantling is a piece sawed on all sides. Shakes are longitudinal splits or cracks in the wood due to shrinkage or decay. Some woods, such as fir, are obtainable in immense quantities, and can thus be used for general construction. Other woods are available only in small quantities and are used for their special characteristics. Limewood, for example, from the lime tree *Tilia cordata*, has a fine, close grain, cutting well in all directions, and is used for carving.

**Wood flour.** Finely ground dried wood employed as a filler and reinforcing material in molding plastics, in linoleum, and as an absorbent for nitroglycerin. It is made largely from light-colored softwoods, chiefly pine and spruce, but maple and ash flours are preferred where no resin content is desired. Woods containing essential oils, such as cedar, are not suitable. Wood flour is produced from sawdust and shavings by grinding in burr mills. It has the appearance of wheat flour. The sizes commonly used are 40, 60, and 80 mesh; the finest is 140 mesh. Grade 1, used as a filler in rubber and plastics, has a particle size of 60 mesh and a specific gravity of 1.25. Since wood flour absorbs the resin or gums when mixed in molding plastics, and sets hard, it is sometimes mixed with mineral powders to vary the hardness and toughness of the molded product.

**Wood's alloy.** A fusible alloy having a low melting point, used for fire extinguisher plugs or for signal alarms. The melting point is about 160°F., and it will melt in contact with hot water. The original Wood's fusible metal, patented in 1860, contained 7 to 8 parts bismuth, 4 lead, 2 tin, and 1 to 2 parts of cadmium. This was the first metal used for automatic sprinkler plugs. The operating temperature of sprinkler plugs in the United States is 160°F., and in England 155°F. Cerrobend, or Bendalloy, is a fusible metal similar to Wood's alloy, marketed by the Cerro de Pasco Copper Company for bending tubing; it melts at 160°F. Cerrosafe, or Safalloy, is a similar alloy used for toy casting sets. See Fusible alloys.

**Wood turpentine.** Also called Spirits of Turpentine, The oil of turpentine obtained from waste wood, chips, or sawdust by

destructive distillation or by steam extraction. Wood turpentine forms more than 10 per cent of all American commercial turpentines. A percentage of pine oil and rosin is also obtained in the process. Wood turpentine has a peculiar characteristic saw-mill odor, and the residue of distillation has a camphorlike odor different from gum turpentine. It differs very little in composition, however, from the true turpentine. Some wood turpentine is also produced as a by-product in the manufacture of cellulose. Sulphite turpentine is a black oil obtained as a by-product in the manufacture of sulphite wood pulp from spruce. It collects on the surface of the liquid in the sulphur dioxide separator. It is purified with soda, and is used chiefly for making toluene and thymol. See also Turpentine.

**Wool.** The fine, soft, curly hair or fleece of the sheep, alpaca, vicuña, certain goats, and a few other animals. The specific designation wool always means the wool of sheep. Sheep's wool is one of the most important commercial fibers. It is used for the production of a great variety of Woolens, or wool fabrics under general trade names such as Flannel, Cheviot, Serge, Broadcloth, and Tweed. Worsteds are wool fabrics made from combed-wool yarn, usually from long, smooth wool. Wool is also employed for packings and for insulation, either loose or felted. It varies greatly in fineness and other qualities, depending largely upon the breed of sheep, but also upon the climate, soil, and food. Warm climates produce fine wools, and hot climates produce thin wiry wools.

Wool quality is by fineness, softness, length, and scaliness. Fiber diameters vary from 0.0025 to 0.0005 in. Long wools are generally heavy. Fibers below 3 in. in length are known as Clothing wool, and those from 3 to 7 in. are called Combing wools. Long wools are fibers longer than 7 in. Fleece wool is the unscoured fiber. It may contain as high as 50 per cent of grease and dirt, but this is the form in which wool is normally shipped because it then has the protection of the wool fat until it is manufactured. Carpet wools are usually long nonresilient fibers from sheep bred in severe climates, such as the Mongolian wool.

Wool differs from hair in fineness and in its felting properties. The latter is due to the fine scales on the wool fibers. These scales vary from 1,000 to 3,000 to the inch, but are not found on ordinary hair. They give to the wool the cohesive qualities. Some animals have both wool and hair, while others have wool only when young. There is no sharp dividing line between wool and hair. The finest of the sheep wools come from the Merino sheep, but these vary according to the age and breeding of the animal. The Lincoln sheep produces the longest fiber. It is lustrous but very coarse. Luster of wool depends upon the size and smoothness of the scales. Crimpiness in wool is due to the open formation of the scales. A fine merino will have 24 crimps per inch; a coarse crossbred will have only 6 per inch. Strength of wool fibers often depends upon the health of the animal and the feeding.

Wool is shipped in bales of 200 kg. The chief producing countries are Australia, Argentina, and Russia. The United States and England are also important producers of wool, and England is the center of wool breeding with more varieties than any other country. See also Shoddy, Cashmere, Alpaca.

**Wrought iron.** The commercially pure iron resulting from the reduction of the carbon in cast iron. It is obtained by melting white cast iron and passing an oxidizing flame over it. The iron is left in a pasty condition full of holes, and is then rolled or hammered to unite it into one mass. Wrought iron is a series of welds and bears slag. It is not suitable for important parts requiring strength, but is very ductile and corrosion resistant. It has a fibrous structure, with fibers of slag extending through the iron in the direction of rolling. The commercial rolled iron has an average elastic limit of 30,000 lb. per sq. in., ultimate strength of 50,000 lb. per sq. in., elongation of 35 per cent, and Brinell hardness of 100. In practice wrought iron may be a very low-carbon steel produced by forging. Wrought iron has less than 0.12 per cent of carbon, usually 0.08 per cent. It contains from 1 to 2 per cent of slag. If 0.35 per cent or more of silicon is present, the iron is "cold short" and will also be difficult to weld. Wrought iron is also produced by the Aston process of "shotting" Bessemer

iron into a ladle of molten slag. The sudden cooling breaks the iron up into small globules and the slag absorbs the gases, thus replacing the expensive puddling process. The shotted ball is rolled similarly to hand-puddled iron.

The quality grades of wrought iron refer to the amount of working which the metal has received. When the word iron is used alone, it generally refers to wrought iron. Wrought iron is chiefly used for rivets, staybolts, water pipes, tank plates, and general forged work. For other uses it is now largely replaced by ingot iron or steels containing only slight percentages of carbon, because of the greater uniformity, and freedom from slag cracks. See also Ingot iron, Electrolytic iron, Merchant bar iron. Iron fibered steel is a name of the Edgar Allen Steel Company, Inc., for rolled soft steel toughened with fine iron wire worked into it. Staybolt iron is an old name for tough and ductile iron made from charcoal iron or from carefully puddled iron, and used for forgings. Lewis iron, of Joseph T. Ryerson & Son, Inc., for staybolts and structural parts, is a highly-refined, hand-puddled iron with a tensile strength up to 52,000 lb. per sq. in. and elongation of 30 per cent.

**Xylonite.** A name sometimes applied to celluloid, but originally a nitrocellulose product invented by Daniel Spill in 1868. It consisted of 40 parts of nitrocellulose, 20 parts of camphor, and 40 parts of linseed or castor oil. Later patents were obtained by the same inventor for gelatinizing the nitrocellulose with a solution of camphor in ethyl alcohol. See Celluloid. Xylonite is at present the trade name of a pyroxylin plastic molding material marketed by the British Xylonite Company.

**Xylyl bromide.** A lachrymatory gas used in chemical warfare. It is made by the action of bromine on xylene in sunlight, and has a composition of $CH_3 \cdot C_6H_4 \cdot CH_2Br$. It is a colorless liquid with a specific gravity of 1.371 and boiling point 216°C. It is employed in high-explosive shells, and the disseminated mist causes a copious flow of tears. The German gas called T-stoff is a mixture of 88 per cent of xylyl bromide with 12 per cent of bromoacetone, or with benzyl bromide.

**Y-alloy.** A light-weight alloy developed by the National Physical Laboratories in England. It contains on an average about 4 per cent of copper, 2 of nickel, 1.5 of magnesium, and the balance aluminum. By quenching the hot-rolled alloy at 520°C., a tensile strength of 54,000 lb. per sq. in. has been developed, with elongation of 3 per cent. It is resistant to alternating stresses even at elevated temperatures. It is also resistant to the action of sea water. The specific gravity, sand cast, is 2.73, and wrought, 2.79. The Brinell hardness is 135, and the alloy gives good wearing qualities for automotive pistons. Birmidium is the trade name of the Birmingham Aluminium Company, Ltd., for this alloy. Magnalite, of the Walker M. Levett Company, contains 2.5 per cent of copper, 1.5 nickel, 0.5 zinc, and 1.3 magnesium. The tensile strength of the cast metal is 26,000 lb. per sq. in. and specific gravity 2.8. Hiduminium is the trade name for modified Y-alloys developed by the Rolls-Royce laboratory and produced by High Duty Alloys, Ltd. R.R. 50 alloy contains 1.2 per cent of copper, 1.3 nickel, 0.1 magnesium, 0.18 titanium, 1.1 iron, 2.2 silicon, and the remainder aluminum. It has a tensile strength of 13.6 tons per sq. in., elongation of 4.5 per cent, and Brinell hardness of 80 when heat-treated. R.R. 53 alloy has 2.2 per cent of copper, 1.3 nickel, 1.6 magnesium, 0.08 titanium, 1.4 iron, and 1.2 silicon. The tensile strength is 16.2 tons per sq. in. With more silicon, up to 2 per cent, this alloy is used for fine die castings.

The Y-alloy employed by one of the large airplane engine builders contains 3.5 to 4.75 per cent of copper, 1.75 to 2.25 of nickel, 1.25 to 1.75 of magnesium, a maximum of 0.75 of iron, a maximum of 0.50 of silicon, and the balance aluminum. This is practically British Engineering Standard alloy L24. The untreated castings have a tensile strength of 24,000 lb. per sq. in. and a Brinell hardness of 80. When quenched from 950°F., and aged at 450°F. they have a hardness of 95 and a tensile strength of 30,000 lb. per sq. in. Bohnalite Y, of the Bohn Aluminum and Brass Corporation, has 4 per cent copper, 1.5 magnesium, and 2 nickel. Y-alloy is, however, difficult to cast, and is frequently replaced by alloys with higher copper and small amounts of manganese.

**Yellow casting brass.** The commercial name of yellow-colored brasses capable of making clean, dense castings, and used for the general casting of machine parts except bearings. A composition used by the General Motors Corporation is 63.5 per cent of copper, 33.5 per cent of zinc, and 3 per cent of lead. The ultimate strength is 25,000 lb. per sq. in., and the elongation is 20 per cent. The Yellow brass of the old ship-builders, mixed in the proportions of 16 lb. of copper, 8 zinc, and 0.5 lead, contained about 65 per cent copper, 2 lead, and 33 zinc. Another brass giving dense and tough castings is made from 85 per cent of copper, 5 of tin, 5 of lead, and 5 of zinc. It is poured at from 1600 to 1800°F. See Ounce metal. Yellow brass for general service is frequently cast from A.S.T.M. brass ingot metal No. 6, which contains 22 per cent of zinc, 4 lead, 2 tin, and the balance copper. It has a tensile strength of 20,000 to 25,000 lb. per sq. in., elongation of 15 to 20 per cent, Brinell hardness of 40 to 50, and weight of 535 lb. per cu. ft. For greater hardness and strength more tin is required. Lead improves the machining qualities. All of these mixtures are readily machined.

**Yellow cedar.** The wood of the tree *Chamaecyparis nootkatensis*, or *Cupressus sitkaensis*, which grows on the Pacific Coast from Alaska to Oregon. It is also called Alaska cedar, Yellow cypress, Sitka cypress. The trees reach 6 ft. in diameter. The heartwood is bright yellow and the sapwood slightly lighter. The wood has a fine, uniform grain, is light in weight, moderately hard, easily worked, and durable. It is used for furniture, cabinetwork, boats, and interior finish.

**Ytterbium.** A metallic element, symbol Yb, belonging to the rare-earth group. It was discovered in the mineral gadolinite in 1878. It has not as yet been separated commercially, and is obtained only in the form of its salts.

**Yttrium.** A metallic element, symbol Yt, found in the mineral gadolinite with other rare earths. Metallic yttrium is obtained only with great difficulty. It is a dark-gray powder, having a specific gravity of 3.80 and melting at 1250°C. It decomposes water and is dissolved in most mineral acids. It is not as yet employed commercially.

**Zinc.** A bluish-white metal, symbol Zn. When cast into slabs in the impure form, it is often called spelter. It is obtained chiefly from the minerals sphalerite and calamine. Zinc is hard and brittle, and has a highly crystalline structure when broken. It melts at 787°F. and boils at 1700°F. The specific gravity is 7.142. At about 250°F. it is ductile and can be rolled into thin sheets. The ultimate strength cast is 9,000 lb. per sq. in., with elongation of 1 per cent; the rolled metal has a strength of 24,000 lb. per sq. in. with elongation of 35 per cent. The coefficient of expansion is 0.0000141. Zinc casts readily. On exposure to the air the metal becomes coated with a film of carbonate, and is then very resistant to corrosion. Zinc is employed for galvanizing iron and steel, and in electric batteries. It is also used in sheet or corrugated-sheet form for roofing and siding in building construction. For this use it is hardened with a small amount of copper or other element. Zilloy, of the New Jersey Zinc Company, is the name of a zinc in the form of corrugated sheets, the zinc alloy containing 1 per cent of copper and minute quantities of cadmium and magnesium. Rolled zinc, for making sheet-metal parts, comes in standard gage thicknesses of pure zinc. Zinc is an important metal for alloying with copper in making brasses. Zinc dust and zinc oxide are used for paint making.

The highest grades of commercial zinc are 99.9 per cent pure. Sterling spelter is 99.5 per cent zinc, with a little cadmium, lead, and iron as impurities. Zinc for brass making does not contain more than 0.60 per cent of lead and 0.03 per cent of iron. The Grade D, or Prime western, zinc contains 98 per cent of zinc with lead up to 1.60 per cent as the chief impurity. It is the grade used in galvanizing. Zinc comes in slabs of about 50 lb. each, rolled sheets, plates, and in ribbon with the grain in one direction.

**Zinc-base alloys.** This term now refers usually to alloys of about 92 per cent of zinc with aluminum, copper, and other elements, used for die castings. One of the earliest die-casting alloys, known as Salge's bronze, contained 84 per cent of zinc, 10 tin, 4 copper, 1 lead, and 1 antimony. The alloys with

considerable tin have been replaced by those with aluminum and copper, as the tin alloys had very low strength and were brittle. The alloys produced by the New Jersey Zinc Company under the name of Zamak are in three grades containing about 4.1 per cent of aluminum, with copper from 0 to 2.7 per cent, magnesium 0.03 per cent, and slight amounts of cadmium, lead, magnesium, tin, and iron. The higher copper alloys have greater hardness and strength; the alloy without copper gives greater resistance to corrosion and casts to closer dimensions. Zamak 2, with 4.1 per cent of copper, has a tensile strength of 47,000 lb. per sq. in. with elongation of 5 per cent, as cast. The Brinell hardness is 83, and the weight 0.24 lb. per cu. in. Zamak 3, with no copper, has a tensile strength of 40,000 lb. per sq. in., with elongation of 5 per cent and Brinell hardness of 74. Bunker Hill alloy, produced by the St. Joseph Lead Company, has 4 per cent of aluminum, 3 copper, 0.1 magnesium, and the balance zinc. Apex zinc alloy, of the Apex Smelting Company, has about the same composition. The zinc-base alloys are now fairly closely standardized, but may vary in small proportions of elements, and are sold under many trade names in the cast articles, such as Miller metal, used by the Miller Company for casting lamp and ornamental parts.

Zinc-base alloys are also used for bearings. They have lower antifriction properties, but have high compressive strength and are less expensive than tin alloys. An alloy produced by the Lumen Bronze Company, containing 86 per cent of zinc, 10 copper, and 4 aluminum, has a compressive strength of 75,000 lb. per sq. in., Brinell hardness of 116, and low coefficient of friction. Ehrhard's bearing metal has 2.5 per cent of aluminum, a small amount of tin to form copper-tin crystals, about 1 per cent of lead and 10 copper, with the balance zinc. An alloy known as Fenton's alloy contains 80 per cent of zinc, 14 tin, and 6 copper. It is used for high-speed bearings with low pressure. Binding metal, for wire rope slings, is a hardened zinc alloy. A binding metal used by the Pennsylvania Railroad has 93.5 per cent of zinc, 2.8 tin, and 3.7 antimony.

The War bronze used for bearings to replace bronze when copper was scarce was a zinc alloy containing 5 per cent of

copper and 2 aluminum, with sometimes a very small amount of tin. Leddel alloy is a bearing metal containing 90 per cent zinc, 5 copper, and 5 aluminum. Hartzink is a German alloy hardened with 5 per cent of iron and 2 to 3 of lead. Iron forms with zinc chemical compounds, $FeZn_7$ and $Fe_3Zn_{10}$ crystals, and even small amounts of iron in zinc will reduce malleability. Alloys containing more than 1 per cent of iron are brittle, but the brittleness is not so marked when the copper content is high. Germania bearing bronze, with about 1 per cent of iron, has 80 per cent zinc, about 10 tin, and slightly less than 5 per cent each of copper and lead. Pattern metal, for casting gates of small patterns, may be any brass made with high percentage of zinc and some lead.

A zinc alloy of another class is Eraydo, of the Illinois Zinc Company. It is a patented material composed of zinc, copper, and silver, and is used for radio shields and condenser frames. It has the property of cutting off induction of stray currents from coils and tubes. The tensile strength is 50,000 lb. per sq. in., and it is about 20 per cent lighter in weight than copper. Zam metal is an alloy of zinc with aluminum and mercury produced by the Hanson-Van Winkle-Munning Company for zinc-plating anodes. It has the property of being free from acid attack until the electric current passes through it.

**Zinc chloride.** Also called Butter of zinc, and originally known as Spirits of salts. A white, crystalline, poisonous substance of the composition $ZnCl_2$, used as a soldering flux, for wood preserving, in dry-cell batteries, and in vulcanizing fibers. It has a specific gravity of 2.91 and melts at 262°C. It is soluble in water and in alcohol. It is made by the action of hydrochloric acid on zinc.

**Zinc chromate.** Also called Zinc yellow, and Buttercup yellow. A beautiful, stable, yellow pigment, coming in various tints and used in paints. It is a crystalline powder of the composition $ZnCrO_4$, and specific gravity of 3.5. It is made by adding a hot neutral solution of zinc sulphate to potassium chromate. It does not have the covering power of chrome yellow, but it has the advantage that it does not blacken by exposure to

sulphides. It is used largely for mixing with Prussian blue to form greens. Zinc bichromate, $ZnCr_2O_7$, is an orange-yellow powder also used as a pigment.

**Zincite.** An ore of the metal zinc, but used chiefly for the production of the zinc oxide known as zinc white employed as a pigment. Zincite has the composition ZnO, containing theoretically 80.3 per cent of zinc. The mineral has usually a massive granular structure with a deep-red to orange streaked color. It may be translucent or almost opaque. It is found and worked in New Jersey.

**Zinc powder.** Also known as Zinc dust, although zinc dust is more specifically only the powder produced by the redistillation of zinc drosses. A finely divided gray metallic zinc powder used in paints for the protection of iron and steel against corrosion. An important use, also, is for coating metals by the sherardizing process. It is usually made up with boiled or raw linseed oil, turpentine, and a drier such as manganese resinate. It may also be mixed with 10 to 25 per cent of zinc oxide, to aid in keeping the powder in suspension, to harden the film, and to brighten the color. Zinc powder is a condensed zinc vapor, or an atomized zinc, and is of such fineness that 90 to 95 per cent should pass through a 325-mesh screen. Standard zinc dust contains 96 per cent of metallic zinc and the balance zinc oxide. Zinc powder is easily wetted by oils or lacquers, and does not have to be ground in a paint mill. The specific gravity is 7.06. The paints made with the powder are resistant to weathering. Merrillite is a zinc dust of high purity of the Alloys Company used to precipitate gold and silver by the cyanide process.

**Zinc sulphide.** A yellowish-white powder of the composition $ZnS \cdot H_2O$ and specific gravity 3.98, used as a paint pigment, for whitening rubber products and for whitening paper. About 55 per cent in rubber makes an ivory-colored rubber. Cryptone is a trade name of the New Jersey Zinc Company for various grades of zinc sulphide pigments, varying from 98 per cent pure zinc sulphide to mixtures with barium sulphate, calcium sulphide, or titanium dioxide. See Sphalerite.

**Zinc white.** The common name of Zinc oxide, ZnO, used as a paint pigment and as an activator and a whitener in rubber. In automobile tires it increases the strength and heat conductivity and gives age-resisting properties. It is also called Chinese white. It is made directly from the ore, the mineral zincite, by reducing it in a special furnace with coal and an excess of air. It is also made from metallic zinc by vaporizing and burning the zinc in the air. This method is called the French process. Zinc white is a white powder, having a specific gravity of 5.78. It is insoluble in water. As a pigment it is unaffected by the action of sulphides, and is thus used as an Inside white in paints and enamels. It is also employed in paints for exterior use as it resists the action of ultraviolet rays and retains its whiteness although it is not as whitening as lithopone. Zinc oxide has high electrical resistance, and it is put in insulating cable compounds. It is also used to give color, opacity, and finish to papers. Kadox is a trade name of the New Jersey Zinc Company for pure zinc oxide. Leaded zinc oxide is a pigment consisting of zinc oxide and basic lead sulphate. It may contain from 3 to 25 per cent of lead, but zinc oxide for use in rubber must be lead free as the lead combines with the sulphur. Zinc-white paste should contain 90 per cent of the pigment and 10 of linseed oil. Another white zinc compound, used for flatting paints, is Zinc stearate. It has the composition $Zn(C_{18}H_{35}O_2)_2$, and is a white, agglutinating powder.

**Zirconia.** Zirconium oxide, a white crystalline powder having the composition $ZrO_2$, a specific gravity of 5.75, hardness of 6.5, and refractive index of 2.2. Its chief source is from the mineral Baddeleyite, which comes from Brazil. The melting point is 5350°F. when pure, and it is the most heat resistant of the commercial refractories. It is used as a refractory and in some quartz ware, and as an opacifier in ceramics. Zirconia is also the chief source of the metal zirconium. The type of baddeleyite of Brazil known as Brazilite contains 80 per cent of zirconia; the mineral known as Zirkelite, or Zirconium sand, which is a Zirconium silicate, contains up to 50 per cent. When zirconia is used as a refractory with lime or other material as

a binder, the melting point is lowered. But zirconia may be bonded with itself by grinding 20 per cent of the material to 200 mesh. This ground ore becomes colloidal with water. The coefficient of expansion of zirconia is very low, 0.00000084, and dishes made of it can be plunged white hot into cold water without breaking. The material is also resistant to acids and alkalies. The Zircon found in the beach sands of Florida is Zirconium silicate, $ZrSiO_4$, and is used as a refractory for firebricks and crucibles. The melting point is 1990°C. and the hardness is 7.5 Moh. By heating zirconia with carbon a Zirconium carbide, $ZrC_2$, is formed, which is a very hard abrasive.

**Zirconium.** An elementary metal, symbol Zr, silvery white in color, having a specific gravity of 6.4 and melting point about 3000°F. It occurs chiefly in the minerals zircon and baddeleyite. It is more abundant than nickel but is difficult to reduce to metallic form as it readily combines with oxygen, nitrogen, carbon, and silicon. The metal is not attacked by nitric or sulphuric acid, but is dissolved by hydrofluoric acid. It has been alloyed with nickel for cutting tools and in copper alloys. See Cooperite. It does not make copper sluggish as does titanium, and bronze containing zirconium can be poured freely. Nickel-zirconium is a master alloy used for deoxidizing and adding zirconium to nonferrous alloys, and for degasifying nickel. A nickel-zirconium of the Electro Metallurgical Company has 40 to 50 per cent nickel, 25 to 30 zirconium, 10 aluminum, and a maximum of 10 per cent silicon and 5 iron. Zirconium is also added to steel, and has a powerful deoxidizing action, producing a steel with uniformity of grain. It also combines with the sulphur and reduces hot-shortness in the steel, and also carries off the nitrogen, making a more ductile steel. Steels can be produced without manganese by the use of zirconium. When zirconium is present in steel in amounts above 0.15 per cent, it forms zirconium sulphide and aids the rolling. This compound also aids machinability in stainless steels. Zirconium-copper is a master alloy of zirconium and copper, in two grades, 12.5 and 35 per cent zirconium, used to deoxidize and give hardness and strength to brasses and bronzes. It is

marketed in bars and lumps. Zirconium metal is now marketed in the form of wire, sheet, and foil.

**Zirconium-ferrosilicon.** An alloy of zirconium with iron and silicon, employed for adding zirconium to steel and to special irons. A typical analysis, as given by the Electro Metallurgical Sales Corporation, is 9 to 12 per cent of zirconium, 40 to 47 per cent of silicon, 40 to 45 of iron, and a maximum of 0.20 per cent of carbon. Zirconium deoxidizes the steel, carries off much of the sulphur and nitrogen, and makes a more uniform steel capable of withstanding shocks. When it is desired to add considerable amounts of zirconium without an excessive increase of silicon, a Silicon-zirconium alloy, containing higher percentages of zirconium, is used. These alloys contain from 35 to 40 per cent of zirconium, and about 50 per cent of silicon, with less than 10 per cent of iron.

# APPENDIX

## UNITS OF MEASURE

Unless specifically noted, the units used in this book are as follows: Ton is the long ton of 2,240 pounds; the pound is the avoirdupois pound of 16 ounces, or 7,000 grains; the gallon is the United States gallon of 231 cubic inches.

For vessel, or shipping, capacity the terms "gross" and "net" tonnage refer to space measurement of 100 cubic feet to the ton. Gross tonnage is the capacity of the entire space within spaces above deck. Net, or registered, tonnage is what remains after deducting from the gross tonnage the spaces occupied by machinery, fuel, and quarters, and represents actual space available.

### Useful Conversion Factors

1 pound = 0.4536 kilogram
1 kilogram = 2.205 pounds
1 gram = 15.43 grains = 0.03527 avoirdupois ounce
1 metric ton = 1,000 kilograms = 0.9842 long ton = 1.102 short tons
1 troy ounce = 31.1 grams
1 avoirdupois ounce = 28.35 grams
1 metric carat = 0.200 gram
1 square meter = 1.196 square yards
1 liter = 1.057 liquid quarts
1 bushel = 2,150.4 cubic inches
1 gallon = 231 cubic inches
1 cubic foot = 1,728 cubic inches
Specific gravity × 0.036 = weight in pounds per cubic inch
1 troy pound = 12 ounces
1 carat = 0.205 gram
1 board foot = 144 cubic inches
1 barrel (oils) = 42 gallons
1 tierce (thin-staved cask) = 42 gallons, usually 310 to 370 pounds
1 ligne (metal button measure) = $\frac{1}{40}$ inch
1 iron (leather industry) = $\frac{1}{48}$ inch
1 horsepower = 33,000 foot-pounds per minute = 745.7 watts
1 ft-lb. = 0.0012861 British thermal unit = 0.0000003766 kw.-hr.
1 British thermal unit = 0.0003927 horsepower = 777.54 foot-pounds
1 cheval-vapeur (metric) = 0.9836 horsepower
1 horsepower = 1.0139 force de cheval

## Foreign Units

1 hundredweight (British) = 112 pounds
1 quintal (British Empire) = 112 pounds
1 metric quintal = 100 kilograms = 220.5 pounds
1 imperial bushel (British) = 1.0315 United States bushels
1 imperial gallon (British) = 1.20 United States gallon
1 proof gallon (British) = 1.37 United States proof gallons
1 Ionian pound (Greece) = 1 avoirdupois pound
1 Venetian pound = 1.058 pounds
1 pood (Russian) = 36.11 pounds
1 arshin (Russian) = 28 inches
1 vedro (Russian) = 3.249 gallons
1 picul (China) = 100 catties = 133⅓ pounds
1 picul (East Indies) = 136.2 pounds
1 picul (Japan) = 132.3 pounds
1 koku (Japan) = 47.65 gallons = 5.119 bushels
1 kwan (Japan) = 1,000 momme = 8.267 pounds

## Metric Length Measurements

| Unit | Inches | Feet | Millimeters | Centimeters | Meters |
|---|---|---|---|---|---|
| One inch | 1 | 0.0833 | 25.4 | 2.54 | 0.0254 |
| One foot | 12 | 1 | 304.8 | 30.48 | 0.3048 |
| One millimeter | 0.03937 | 0.00328 | 1 | 0.1 | 0.001 |
| One centimeter | 0.3937 | 0.0328 | 10 | 1 | 0.01 |
| One meter | 39.37 | 3.2809 | 1000 | 100 | 1 |
| One yard | 36 | 3 | 914.4 | 91.44 | 0.9144 |

## Standard Paper Sizes

| | |
|---|---|
| Folio note | 5½ by 8½ in. |
| Pocket note | 6 by 9½ in. |
| U.S. government writing | 8 by 10½ in. |
| Commercial writing | 8½ by 11 in. |
| Legal cap | 8½ by 14 in. |
| Foolscap | 13 by 16 in. |
| Denny | 16 by 21 in. |
| Folio | 17 by 22 in. |
| Royal | 19 by 24 in. |
| Super royal | 20 by 28 in. |
| Elephant | 23 by 28 in. |
| Imperial | 23 by 31 in. |

## Standard Metal Gages

The Brown & Sharpe, or American standard, wire gage is used for aluminum, brass, bronze, and German silver sheet, also for nonferrous wires and rod.

The Birmingham wire gage (B.W.G.), also known as the Stubs' iron wire gage, applies to seamless tubing and to sheet spring steel.

The British imperial gage (B.I.G.), also known as the legal standard gage (L.S.G.), is used in Great Britain, and also in the United States for copper wire.

The Washburn & Moen gage, also known as the Roebling gage, or the national wire gage, applies to all bare, galvanized, and annealed steel and iron wire, and to tinned steel wire and spring steel wire.

The music wire gage is used for "music" wire.

The U.S. standard gage is used for steel and iron plate, galvanized, tinned, or terne.

The twist drill gage, also known as the Morse gage, is used for drill-steel rod. Stubs' steel wire gage is used for steel drill rod. The American screw gage is applied to machine screws. The zinc gage is used for sheet zinc.

## Physical and Chemical Units

**Acid number** is the weight in milligrams of potassium hydroxide required to neutralize the fatty acid in one gram of fat or fatty oil.

**Iodine value** is the number of grams of iodine absorbed by 100 grams of fat or fatty oil. It gives a measure of the chemical unsaturation of an oil or fat. High iodine value, 117 to 206, in vegetable oils, indicates suitability of the oil for use in paints. Low iodine value, not subject to oxidation, indicates non-drying suitable for soaps.

**Saponification value** is the number of milligrams of potassium hydroxide required to saponify one gram of fatty oil or grease.

**Specific gravity** is the ratio of the weight of a given volume of a material to the weight of an equal volume of pure water at 4°C.

**Specific heat** is the number of calories required to raise 1 gram of the material 1°C. in temperature.

**Thermal conductivity** is the number of calories transmitted per second between opposite faces of a cube, 1 centimeter by 1 centimeter by 1 centimeter, when the difference between the opposite faces of the cube is 1°C.

**Thermal expansion.** The coefficient of linear thermal expansion is the increase in unit length with each change of 1 deg. in temperature.

## Metal Gages in Common Use

| Gage No. | Brown & Sharpe | Birmingham wire | British Imperial wire | Washburn & Moen | Music wire | U.S. Standard Plate | Twist drill | Stubs steel wire | American screw | Zinc |
|---|---|---|---|---|---|---|---|---|---|---|
| 7-0 | ...... | .. .. | 0 500 | 0.4900 | . | 0 5000 | | | | |
| 6-0 | .... . | .. .. | 0.464 | 0.4600 | | 0 4690 | | | | |
| 5-0 | ..... | .. | 0 432 | 0 4300 | . .. | 0 4380 | | | | |
| 4-0 | 0.4600 | 0 454 | 0 400 | 0 3940 | . . | 0 4060 | | | | |
| 3-0 | 0.4100 | 0 425 | 0 372 | 0 3630 | . . . | 0 3750 | .... | . . | 0.0315 | |
| 2-0 | 0 3650 | 0 380 | 0 348 | 0 3310 | 0.0085 | 0.3440 | . | ... | 0 0447 | |
| 0 | 0 3250 | 0 340 | 0.324 | 0 3070 | 0.0090 | 0.3130 | .. | .... | 0 0578 | |
| 1 | 0 2890 | 0 300 | 0.300 | 0.2830 | 0.0100 | 0.2810 | 0 2280 | 0 227 | 0 0710 | 0 002 |
| 2 | 0 2580 | 0.284 | 0 276 | 0.2630 | 0 0110 | 0.2660 | 0 2210 | 0.219 | 0 0842 | 0.004 |
| 3 | 0.2290 | 0 259 | 0.252 | 0.2440 | 0 0120 | 0.2500 | 0 2130 | 0 212 | 0 0973 | 0 006 |
| 4 | 0.2040 | 0.238 | 0.232 | 0 2250 | 0.0130 | 0.2340 | 0.2090 | 0 207 | 0.1100 | 0 008 |
| 5 | 0.1820 | 0 220 | 0 212 | 0 2070 | 0.0140 | 0.2190 | 0.2055 | 0 204 | 0 1240 | 0 010 |
| 6 | 0 1620 | 0 203 | 0 192 | 0.1920 | 0.0160 | 0.2030 | 0.2040 | 0.201 | 0 1370 | 0.012 |
| 7 | 0.1440 | 0.180 | 0.176 | 0.1770 | 0.0180 | 0.1880 | 0.2010 | 0.199 | 0.1500 | 0.014 |
| 8 | 0.1290 | 0 165 | 0 160 | 0.1620 | 0 0200 | 0.1720 | 0 1990 | 0.197 | 0 1630 | 0 016 |
| 9 | 0.1140 | 0 148 | 0.144 | 0.1480 | 0.0220 | 0.1560 | 0.1960 | 0 194 | 0.1760 | 0.018 |
| 10 | 0.1020 | 0.134 | 0 128 | 0.1350 | 0.0240 | 0.1410 | 0.1940 | 0.191 | 0.1890 | 0 020 |
| 11 | 0.0907 | 0.120 | 0.116 | 0.1210 | 0.0260 | 0.1250 | 0 1910 | 0.188 | 0.2030 | 0.024 |
| 12 | 0.0808 | 0 109 | 0.104 | 0.1060 | 0 0280 | 0.1090 | 0.1890 | 0.185 | 0.2160 | 0 028 |
| 13 | 0 0720 | 0 095 | 0.092 | 0.0915 | 0 0300 | 0.0938 | 0.1850 | 0.182 | 0.2290 | 0.032 |
| 14 | 0.0641 | 0.083 | 0.080 | 0.0800 | 0.0320 | 0.0781 | 0.1820 | 0.180 | 0.2420 | 0.036 |
| 15 | 0.0571 | 0.072 | 0.072 | 0.0720 | 0.0340 | 0.0703 | 0.1800 | 0.178 | 0.2550 | 0.040 |
| 16 | 0.0508 | 0 065 | 0.064 | 0.0625 | 0.0360 | 0.0625 | 0.1770 | 0.175 | 0.2680 | 0.045 |
| 17 | 0.0453 | 0.058 | 0.056 | 0.0540 | 0.0380 | 0.0563 | 0.1730 | 0.172 | 0.2820 | 0.050 |
| 18 | 0.0403 | 0 049 | 0.048 | 0.0475 | 0.0400 | 0.0500 | 0.1695 | 0 168 | 0.2950 | 0.055 |
| 19 | 0.0359 | 0.042 | 0.040 | 0.0410 | 0.0420 | 0.0438 | 0.1660 | 0.164 | 0.3080 | 0.060 |
| 20 | 0.0320 | 0.035 | 0.036 | 0.0348 | 0.0440 | 0.0375 | 0.1610 | 0.161 | 0.3210 | 0.070 |
| 21 | 0.0285 | 0.032 | 0 032 | 0.0318 | 0.0460 | 0.0344 | 0.1590 | 0.157 | 0.3340 | 0.080 |
| 22 | 0.0254 | 0.028 | 0.028 | 0.0286 | 0.0480 | 0.0313 | 0.1570 | 0.155 | 0.3470 | 0.090 |
| 23 | 0.0226 | 0.025 | 0.024 | 0.0258 | 0.0510 | 0 0281 | 0.1540 | 0.153 | 0.3610 | 0.100 |
| 24 | 0.0201 | 0.022 | .0 022 | 0.0230 | 0.0550 | 0 0250 | 0.1520 | 0.151 | 0.3740 | 0.125 |
| 25 | 0.0179 | 0.020 | 0 020 | 0.0204 | 0.0590 | 0 0219 | 0.1500 | 0 148 | 0.3870 | 0.250 |

**Metal Gages in Common Use.**—(*Continued*)

| Gage No. | Brown & Sharpe | Birming-ham wire | British Imperial wire | Wash-burn & Moen | Music wire | U.S. Stand-ard Plate | Twist drill | Stubs steel wire | Ameri-can screw | Zinc |
|---|---|---|---|---|---|---|---|---|---|---|
| 26 | 0.0159 | 0.018 | 0.018 | 0.0181 | 0.0630 | 0.0188 | 0.1470 | 0.146 | 0.4000 | 0.375 |
| 27 | 0.0142 | 0.016 | 0.0164 | 0.0173 | 0.0670 | 0.0172 | 0.1440 | 0.143 | 0.4130 | 0.500 |
| 28 | 0.0126 | 0.014 | 0.0148 | 0.0162 | 0.0710 | 0.0156 | 0.1410 | 0.139 | 0.4260 | 1.000 |
| 29 | 0.0113 | 0.013 | 0.0136 | 0.0150 | 0.0740 | 0.0141 | 0.1360 | 0.134 | 0.4390 | |
| 30 | 0.0100 | 0.012 | 0.0124 | 0.0140 | 0.0780 | 0.0125 | 0.1285 | 0.127 | 0.4530 | |
| 31 | 0.0089 | 0.010 | 0.0116 | 0.0132 | 0.0820 | 0.0109 | 0.1200 | 0.120 | 0.4660 | |
| 32 | 0.0079 | 0.009 | 0.0108 | 0.0128 | 0.0860 | 0.0101 | 0.1150 | 0.115 | 0.4790 | |
| 33 | 0.0071 | 0.008 | 0.0100 | 0.0118 | 0.0900 | 0.0094 | 0.1130 | 0.112 | 0.4920 | |
| 34 | 0.0063 | 0.007 | 0.0092 | 0.0104 | 0.0940 | 0.0086 | 0.1110 | 0.110 | 0.5050 | |
| 35 | 0.0056 | 0.005 | 0.0084 | 0.0095 | 0.0980 | 0.0078 | 0.1100 | 0.108 | 0.5180 | |
| 36 | 0.0050 | 0.004 | 0.0076 | 0.0090 | 0.1020 | 0.0070 | 0.1065 | 0.106 | 0.5320 | |
| 37 | 0.0044 | ..... | 0.0068 | 0.0085 | 0.1060 | 0.0066 | 0.1040 | 0.103 | 0.5450 | |
| 38 | 0.0040 | ..... | 0.0060 | 0.0080 | 0.1120 | 0.0063 | 0.1015 | 0.101 | 0.5580 | |
| 39 | 0.0035 | ..... | 0.0052 | 0.0075 | 0.1180 | ..... | 0.0995 | 0.099 | 0.5710 | |
| 40 | 0.0031 | ..... | 0.0048 | 0.0070 | 0.1250 | ..... | 0.0980 | 0.097 | 0.5840 | |
| 41 | ..... | ..... | 0.0044 | 0.0066 | ..... | ..... | 0.0960 | 0.095 | 0.597 | |
| 42 | ..... | ..... | 0.0040 | 0.0062 | ..... | ..... | 0.0935 | 0.092 | 0.611 | |
| 43 | ..... | ..... | 0.0036 | 0.0060 | ..... | ..... | 0.0890 | 0.088 | 0.624 | |
| 44 | ..... | ..... | 0.0032 | 0.0058 | ..... | ..... | 0.0860 | 0.085 | 0.637 | |
| 45 | ..... | ..... | 0.0028 | 0.0055 | ..... | ..... | 0.0820 | 0.081 | 0.650 | |
| 46 | ..... | ..... | 0.0024 | 0.0052 | ..... | ..... | 0.0810 | 0.079 | 0.663 | |
| 47 | ..... | ..... | 0.0020 | 0.0050 | ..... | ..... | 0.0785 | 0.077 | 0.676 | |
| 48 | ..... | ..... | 0.0016 | 0.0048 | ..... | ..... | 0.0760 | 0.075 | 0.690 | |
| 49 | ..... | ..... | 0.0012 | 0.0046 | ..... | ..... | 0.0730 | 0.072 | 0.703 | |
| 50 | ..... | ..... | 0.0010 | 0.0044 | ..... | ..... | 0.0700 | 0.069 | 0.716 | |
| 51 | ..... | ..... | ..... | ..... | ..... | ..... | 0.0670 | | | |
| 52 | ..... | ..... | ..... | ..... | ..... | ..... | 0.0635 | | | |
| 53 | ..... | ..... | ..... | ..... | ..... | ..... | 0.0595 | | | |
| 54 | ..... | ..... | ..... | ..... | ..... | ..... | 0.0550 | | | |
| 55 | ..... | ..... | ..... | ..... | ..... | ..... | 0.0520 | | | |
| 56 | ..... | ..... | ..... | ..... | ..... | ..... | 0.0465 | | | |
| 57 | ..... | ..... | ..... | ..... | ..... | ..... | 0.0430 | | | |
| 58 | ..... | ..... | ..... | ..... | ..... | ..... | 0.0420 | | | |
| 59 | ..... | ..... | ..... | ..... | ..... | ..... | 0.0410 | | | |
| 60 | ..... | ..... | ..... | ..... | ..... | ..... | 0.0400 | | | |

## Hardness Numbers

The Brinell method of determining hardness is by the indentation effect of a hard ball pressed into the surface of the metal to be tested. Tables of hardness numbers corresponding to the various indentation measurements are furnished by the makers.

The Scleroscope, or "Shore," method measures hardness by a comparison of the effect of the drop and rebound of a diamond-tipped hammer dropping by gravity from a fixed height. The resulting rebound is then read on a graduated scale.

The Rockwell hardness tester measures hardness by determining the depth of penetration under load of a steel ball or diamond cone in the material being tested. Rockwell hardness is expressed as a number, which is read on a graduated gage.

The Moh hardness scale for abrasives and minerals is measured by scratch comparison, the mineral talc being taken as 1, and the diamond as 10 on the scale.

### Scale of Hardness for Minerals—Moh Scale

| Mineral | Hardness number | Mineral | Hardness number |
|---|---|---|---|
| Talc | 1 | Orthoclase | 6 |
| Gypsum | 2 | Quartz | 7 |
| Calcite | 3 | Topaz | 8 |
| Fluorite | 4 | Corundum | 9 |
| Apatite | 5 | Diamond | 10 |

### Hardness Grades in Woods

1. Excessively hard. Lignum-vitae, Ebony
2. Extremely hard. Boxwood, Lilac, Jarrah, Karri
3. Very hard.... . Whitehorn, Blackthorn, Persimmon
4. Hard.......... Hornbeam, Elder, Yew
5. Rather hard.... Ash, Holly, Plum, Elm
6. Firm........... Teak, Chestnut, Beech, Walnut, Apple, Oak
7. Soft........... Willow, Deal, Alder, Australian red cedar, Birch, Hazel
8. Very soft....... White pine, Poplar, Redwood.

**Approximate Relationship of Rockwell, Scleroscope, and Brinell Hardness Numbers**

| Rockwell | Scleroscope | Brinell | Rockwell | Scleroscope | Brinell |
|---|---|---|---|---|---|
| 1 | .. | 158 | 31 | 43 | 294 |
| 2 | .. | 160 | 32 | 44 | 301 |
| 3 | .. | 162 | 33 | 45 | 309 |
| 4 | .. | 165 | 34 | 46 | 318 |
| 5 | .. | 168 | 35 | 47 | 327 |
| 6 | .. | 171 | 36 | 48 | 337 |
| 7 | . | 174 | 37 | 50 | 347 |
| 8 | 28 | 177 | 38 | 51 | 357 |
| 9 | 29 | 180 | 39 | 52 | 367 |
| 10 | 29 | 183 | 40 | 53 | 377 |
| 11 | 29 | 186 | 41 | 54 | 387 |
| 12 | 29 | 190 | 42 | 56 | 398 |
| 13 | 30 | 193 | 43 | 57 | 408 |
| 14 | 30 | 197 | 44 | 58 | 419 |
| 15 | 30 | 201 | 45 | 59 | 430 |
| 16 | 31 | 206 | 46 | 61 | 442 |
| 17 | 32 | 210 | 47 | 62 | 453 |
| 18 | 32 | 215 | 48 | 63 | 464 |
| 19 | 33 | 220 | 49 | 65 | 476 |
| 20 | 33 | 225 | 50 | 66 | 488 |
| 21 | 34 | 230 | 51 | 67 | 500 |
| 22 | 35 | 235 | 52 | 69 | 512 |
| 23 | 36 | 241 | 53 | 70 | 524 |
| 24 | 36 | 247 | 54 | 71 | 536 |
| 25 | 37 | 253 | 55 | 73 | 548 |
| 26 | 38 | 259 | 56 | 74 | 561 |
| 27 | 39 | 265 | 57 | 76 | 574 |
| 28 | 40 | 272 | 58 | 77 | 584 |
| 29 | 41 | 279 | 59 | 78 | 600 |
| 30 | 42 | 286 | 60 | 80 | 613 |

## Temperature Conversion Scale

To change a temperature in degrees centigrade, to degrees Fahrenheit, multiply by $\frac{9}{5}$ and add 32, thus, $F = \frac{9}{5}(C + 32)$. To change degrees Fahrenheit, to degrees centigrade, subtract 32 and multiply by $\frac{5}{9}$, thus $C = \frac{5}{9}(F - 32)$.

| C. | F. | C. | F. | C. | F. | C. | F. | C. | F. |
|---|---|---|---|---|---|---|---|---|---|
| 0 | 32 | 230 | 446 | 460 | 860 | 690 | 1274 | 920 | 1688 |
| 5 | 41 | 235 | 455 | 465 | 869 | 695 | 1283 | 925 | 1697 |
| 10 | 50 | 240 | 464 | 470 | 878 | 700 | 1292 | 930 | 1706 |
| 15 | 59 | 245 | 473 | 475 | 887 | 705 | 1301 | 935 | 1715 |
| 20 | 68 | 250 | 482 | 480 | 896 | 710 | 1310 | 940 | 1724 |
| 25 | 77 | 255 | 491 | 485 | 905 | 715 | 1319 | 945 | 1733 |
| 30 | 86 | 260 | 500 | 490 | 914 | 720 | 1328 | 950 | 1742 |
| 35 | 95 | 265 | 509 | 495 | 923 | 725 | 1337 | 955 | 1751 |
| 40 | 104 | 270 | 518 | 500 | 932 | 730 | 1346 | 960 | 1760 |
| 45 | 113 | 275 | 527 | 505 | 941 | 735 | 1355 | 965 | 1769 |
| 50 | 122 | 280 | 536 | 510 | 950 | 740 | 1364 | 970 | 1778 |
| 55 | 131 | 285 | 545 | 515 | 959 | 745 | 1373 | 975 | 1787 |
| 60 | 140 | 290 | 554 | 520 | 968 | 750 | 1382 | 980 | 1796 |
| 65 | 149 | 295 | 563 | 525 | 977 | 755 | 1391 | 985 | 1805 |
| 70 | 158 | 300 | 572 | 530 | 986 | 760 | 1400 | 990 | 1814 |
| 75 | 167 | 305 | 581 | 535 | 995 | 765 | 1409 | 995 | 1823 |
| 80 | 176 | 310 | 590 | 540 | 1004 | 770 | 1418 | 1000 | 1832 |
| 85 | 185 | 315 | 599 | 545 | 1013 | 775 | 1427 | 1005 | 1841 |
| 90 | 194 | 320 | 608 | 550 | 1022 | 780 | 1436 | 1010 | 1850 |
| 95 | 203 | 325 | 617 | 555 | 1031 | 785 | 1445 | 1015 | 1859 |
| 100 | 212 | 330 | 626 | 560 | 1040 | 790 | 1454 | 1020 | 1868 |
| 105 | 221 | 335 | 635 | 565 | 1049 | 795 | 1463 | 1025 | 1877 |
| 110 | 230 | 340 | 644 | 570 | 1058 | 800 | 1472 | 1030 | 1886 |
| 115 | 239 | 345 | 653 | 575 | 1067 | 805 | 1481 | 1035 | 1895 |
| 120 | 248 | 350 | 662 | 580 | 1076 | 810 | 1490 | 1040 | 1904 |
| 125 | 257 | 355 | 671 | 585 | 1085 | 815 | 1499 | 1045 | 1913 |
| 130 | 266 | 360 | 680 | 590 | 1094 | 820 | 1508 | 1050 | 1922 |
| 135 | 275 | 365 | 689 | 595 | 1103 | 825 | 1517 | 1055 | 1931 |
| 140 | 284 | 370 | 698 | 600 | 1112 | 830 | 1526 | 1060 | 1940 |
| 145 | 293 | 375 | 707 | 605 | 1121 | 835 | 1535 | 1065 | 1949 |
| 150 | 302 | 380 | 716 | 610 | 1130 | 840 | 1544 | 1070 | 1958 |
| 155 | 311 | 385 | 725 | 615 | 1139 | 845 | 1553 | 1075 | 1967 |
| 160 | 320 | 390 | 734 | 620 | 1148 | 850 | 1562 | 1080 | 1976 |
| 165 | 329 | 395 | 743 | 625 | 1157 | 855 | 1571 | 1085 | 1985 |
| 170 | 338 | 400 | 752 | 630 | 1166 | 860 | 1580 | 1090 | 1994 |
| 175 | 347 | 405 | 761 | 635 | 1175 | 865 | 1589 | 1095 | 2003 |
| 180 | 356 | 410 | 770 | 640 | 1184 | 870 | 1598 | 1100 | 2012 |
| 185 | 365 | 415 | 779 | 645 | 1193 | 875 | 1607 | 1105 | 2021 |
| 190 | 374 | 420 | 788 | 650 | 1202 | 880 | 1616 | 1110 | 2030 |
| 195 | 383 | 425 | 797 | 655 | 1211 | 885 | 1625 | 1115 | 2039 |
| 200 | 392 | 430 | 806 | 660 | 1220 | 890 | 1634 | 1120 | 2048 |
| 205 | 401 | 435 | 815 | 665 | 1229 | 895 | 1643 | 1125 | 2057 |
| 210 | 410 | 440 | 824 | 670 | 1238 | 900 | 1652 | 1130 | 2066 |
| 215 | 419 | 445 | 833 | 675 | 1247 | 905 | 1661 | 1135 | 2075 |
| 220 | 428 | 450 | 842 | 680 | 1256 | 910 | 1670 | 1140 | 2084 |
| 225 | 437 | 455 | 851 | 685 | 1265 | 915 | 1679 | 1045 | 2093 |

### Elementary Material Units

**Element.** A substance composed of molecules whose atoms are all alike.

**Compound.** A substance, the molecules of which are alike, but the atoms dissimilar.

**Mixture.** A substance made up of dissimilar molecules not chemically combined.

**Solution.** A mixture, either liquid or solid, which is homogeneous to a high degree.

**Molecule.** Two or more atoms united to form a material dissimilar from the original atoms.

**Atom.** The smallest particles of an element still retaining the characteristics of the element, which cannot be broken up by ordinary chemical means.

**Ion.** A part of a molecule bearing one or more electric charges.

**Electrons.** The negative charges of electricity into which atoms are broken up by radioactivity or X rays.

**Nuclei.** The positive charge of electricity contained within the negative charges of an atom.

# PHYSICAL PROPERTIES OF MATERIALS

## Linear Expansion of Metals

Unit length increase per degree centigrade rise in temperature

| | |
|---|---|
| Cast iron | 0.000010 |
| Steel | 0.000011 |
| Cobalt | 0.000012 |
| Bismuth | 0.000013 |
| Gold | 0 000014 |
| Nickel | 0.000014 |
| Copper | 0.000017 |
| Brass | 0.000019 |
| Silver | 0 000019 |
| Tobin bronze | 0 000021 |
| Aluminum | 0.000024 |
| Zinc | 0.000026 |
| Tin | 0.000027 |
| Lead | 0.000028 |
| Cadmium | 0 000029 |
| Magnesium | 0.000029 |

## Comparative Hardness of Hard Abrasives

(Scale: Diamond 10, Corundum 9)

| | |
|---|---|
| South American brown bort | 10.00 |
| South American Ballas | 9.99 |
| Belgian Congo yellow (cubic crystals) | 9.96 |
| Belgian Congo clear white (cubic crystals) | 9 95 |
| Belgian Congo gray opaque (cubic crystals) | 9.89 |
| South American carbonados | 9.82 |
| Boron carbide | 9.32 |
| Black silicon carbide | 9.15 |
| Green silicon carbide | 9.13 |
| Tungsten carbide (13 per cent cobalt) | 9.09 |
| Fused alumina (3.14 per cent $TiO_2$) | 9.06 |
| Fused alumina | 9.03 |
| African crystal corundum | 9 00 |
| Rock-crystal quartz | 8.94 |

## Definitions of Physical Properties

**Brittleness.** The property of breaking without perceptible warning or without visible deformation.

**Conductivity.** The relative rate at which a material conducts heat or electricity at normal temperature (60°F.). Silver is the standard of reference as it is the best known conductor of both heat and electricity.

**Ductility.** The property of being permanently deformed by tension without rupture, that is, the ability to be drawn from a large to a small size.

**Elasticity.** The ability of a material to resume its original form after the removal of the force which has produced a change in form. A substance is highly elastic which is easily deformed and quickly recovers.

**Elastic limit.** The greatest unit stress that a material is capable of withstanding without permanent deformation.

**Elongation.** The increase in length of a bar or section under test expressed as a percentage difference between the original length and the length at the moment of rupture.

**Factor of safety.** The ratio of the ultimate strength of a material to its working stress.

**Flow, or "creep."** The gradual continuous distortion of a material under continued load, usually at high temperatures.

**Fusibility.** The ease with which a material is melted.

**Hardness.** A property applied to solids and very viscous liquids to indicate solidity and firmness in substance or outline. A hard substance does not readily receive an indentation.

**Hygroscopic.** Readily absorbing and retaining moisture.

**Impact strength.** The force in foot-pounds required to break the material when applied with a sudden blow.

**Malleability.** The property of being permanently deformed by compression without rupture, that is, the ability to be rolled or hammered into thin sheets.

**Modulus of elasticity.** The ratio of the unit stress to the unit strain.

**Modulus of rigidity.** When an elastic material is subjected to a shearing stress, a displacement takes place; the ratio of the unit shearing stress to the displacement per unit length is the modulus of rigidity.

**Plasticity.** The property in a material of being deformed under the action of a force and not returning to its original shape upon the removal of the force.

**Porosity.** The ratio of the volume of the interstices of a material to the volume of its mass.

**Reduction of area.** The percentage difference between the area of a bar before being subjected to stress and the area of the bar after rupture.

**Resilience.** The energy of elasticity, that is, the energy stored in a material under strain within its elastic limit which will cause it to resume its original shape when the extreme stress is removed. The modulus of resilience is the capacity of a unit volume to store energy up to the elastic limit.

**Shrinkage.** The diminution in dimensions and mass of a material.

**Solubility.** Capacity for being dissolved in a liquid so that it will not separate out on standing, except the excess over the percentage which the liquid (solvent) will dissolve. A suspension is a physical dispersion of particles sufficiently large that physical forces control their dissolution in the liquid. A colloidal solution is a dispersion of particles so finely divided that surface phenomena and kinetic energy control their behavior in the liquid. A colloidal solution is close to a molecular combination. An Emulsion is simply a solution with the particles in an unbalanced suspension which will separate out on standing.

**Stiffness.** The material property which is measured by the rate at which the stress in a material increases with the strain.

**Strain.** The distortion set up in a material by the action of an external force.

**Strength.** The ability to resist physical forces imposed during handling or use.

**Stress.** Internal forces set up in a material by the action of an external force.

**Tensile strength.** The maximum tensile load per square unit of original cross section that a material is able to withstand. Tensile strength is the most common measure of the strength and ductility of metals.

**Thermoplastic.** Capable of being molded without rupture by heat and pressure at temperatures slightly above normal.

**Toughness.** The relative degree of resistance to impact without fracture; the property of a material which enables it to absorb energy while being stressed above its elastic limit but without being fractured.

**Ultimate strength.** The stress, calculated on the maximum value of the force and the original area of cross section, which causes fracture of the material.

**Yield point.** The minimum tensile stress required to produce continuous deformation in a solid material.

## Modulus of Elasticity in Tension of Typical Materials

| | |
|---|---|
| Lead (cast) | 700,000 |
| Lead (hard-drawn) | 1,000,000 |
| Bakelite (fabric laminated) | 1,000,000 |
| Pine (static bending) | 1,200,000 |
| Ash (static bending) | 1,300,000 |
| Bakelite (paper base) | 2,100,000 |
| Tin (cast) | 4,000,000 |
| Tin (rolled) | 5,700,000 |
| Glass | 8,000,000 |
| Brass | 9,000,000 |
| Aluminum (cast) | 10,000,000 |
| Duralumin | 10,000,000 |
| Copper (cast) | 11,000,000 |
| Zinc (cast) | 11,000,000 |
| Zinc (rolled) | 12,000,000 |
| Cast iron | 12,000,000 |
| Brass (cast) | 13,000,000 |
| Bronze (average) | 13,000,000 |
| Phosphor bronze | 13,000,000 |
| Manganese bronze (cast) | 14,000,000 |
| Slate | 14,000,000 |
| Copper (soft, wrought) | 15,000,000 |
| Duronze | 15,500,000 |
| Clock brass | 16,600,000 |
| Copper (hard-drawn) | 18,000,000 |
| Meehanite metal | 22,000,000 |
| Monel metal | 23,000,000 |
| Malleable iron | 23,000,000 |
| Wrought iron | 27,000,000 |
| Carbon steel | 30,000,000 |
| Nickel | 30,000,000 |
| Tungsten | 60,000,000 |

## Order of Ductility of Metals

1. Gold
2. Platinum
3. Silver
4. Iron
5. Copper
6. Aluminum
7. Nickel
8. Zinc
9. Tin
10. Lead

**The Elements**

| Name | Atomic number | Symbol | Atomic weight O = 16.0000 | Melting point, deg. C. |
|---|---|---|---|---|
| Actinium | 89 | Ac | ... .. . | 1800 |
| Alabamine | 85 | Am | .. . | 470 |
| Aluminum | 13 | Al | 26 97 | 660 0 |
| Antimony | 51 | Sb | 121 76 | 630 5. |
| Argon | 18 | A | 39 944 | −189.3 |
| Arsenic | 33 | As | 74 91 | 814 |
| Barium | 56 | Ba | 137 36 | 704 |
| Beryllium | 4 | Be | 9 02 | 1280 |
| Bismuth | 83 | Bi | 209 00 | 271.3 |
| Boron | 5 | B | 10.82 | 2300 |
| Bromine | 35 | Br | 79.916 | −7.2 |
| Cadmium | 48 | Cd | 112.41 | 320.9 |
| Calcium | 20 | Ca | 40 08 | 850 |
| Carbon | 6 | C | 12 00 | 3700 |
| Cerium | 58 | Ce | 140.13 | 600 |
| Cesium | 55 | Cs | 132 91 | 28 |
| Chlorine | 17 | Cl | 35.457 | −101 |
| Chromium | 24 | Cr | 52 01 | 1800 |
| Cobalt | 27 | Co | 58 94 | 1490 |
| Columbium | 41 | Cb | 92 91 | 2000 |
| Copper | 29 | Cu | 63 57 | 1083.0 |
| Dysprosium | 66 | Dy | 162.46 | |
| Erbium | 68 | Er | 167.64 | |
| Europium | 63 | Eu | 152.0 | |
| Fluorine | 9 | Fl | 19.00 | −223 |
| Gadolinium | 64 | Gd | 157.3 | |
| Gallium | 31 | Ga | 69.72 | 29.78 |
| Germanium | 32 | Ge | 72 60 | 958 |
| Gold | 79 | Au | 197.2 | 1063.0 |
| Hafnium | 72 | Hf | 178 6 | 1700 |
| Helium | 2 | He | 4 002 | −271.4 |
| Holmium | 67 | Ho | 163.5 | |
| Hydrogen | 1 | H | 1 0078 | −259.2 |
| Illinium | 61 | Il | 140.0 | |
| Indium | 49 | In | 114.76 | 156.4 |
| Iodine | 53 | I | 126.92 | 114 |
| Ionium | 90 | Io | 230.0 | |
| Iridium | 77 | Ir | 193 1 | 2454 |
| Iron | 26 | Fe | 55.84 | 1535 |
| Krypton | 36 | Kr | 83 7 | −157 |
| Lanthanum | 57 | La | 138 92 | 826 |
| Lead | 82 | Pb | 207 22 | 327.4 |
| Lithium | 3 | Li | 6.940 | 186 |
| Lutecium | 71 | Lu | 175.0 | |
| Magnesium | 12 | Mg | 24.32 | 650 |
| Manganese | 25 | Mn | 54.93 | 1260 |
| Masurium | 43 | Ma | 97.8 | 2300 |
| Mercury | 80 | Hg | 200.61 | −38.87 |
| Molybdenum | 42 | Mo | 96.0 | 2625 |
| Neodymium | 60 | Nd | 144.27 | 840 |
| Neon | 10 | Ne | 20.183 | −248.6 |

**The Elements.**—*Continued*

| Name | Atomic number | Symbol | Atomic weight O = 16.0000 | Melting point, deg. C. |
|---|---|---|---|---|
| Nickel | 28 | Ni | 58 69 | 1455 |
| Nitrogen | 7 | N | 14.008 | −210.0 |
| Osmium | 76 | Os | 191 5 | 2700 |
| Oxygen | 8 | O | 16.0000 | −218 8 |
| Palladium | 46 | Pd | 106.7 | 1554 |
| Phosphorus | 15 | P | 31.02 | 44.1 |
| Platinum | 78 | Pt | 195.23 | 1773 5 |
| Polonium | 84 | Po | ....... | 1800 |
| Potassium | 19 | K | 39.096 | 63 |
| Praseodymium | 59 | Pr | 140.92 | 940 |
| Protoactinium | 91 | Pa | 231 | |
| Radium | 88 | Ra | 226.05 | 700 |
| Radon | 86 | Rn | 222 | −71 |
| Rhenium | 75 | Re | 186.31 | 3000 |
| Rhodium | 45 | Rh | 102.91 | 1966 |
| Rubidium | 37 | Rb | 84.44 | 39 |
| Ruthenium | 44 | Ru | 101.7 | 2450 |
| Samarium | 62 | Sm | 150 43 | 1300 |
| Scandium | 21 | Sc | 45.10 | 1200 |
| Selenium | 34 | Se | 78 96 | 220 |
| Silicon | 14 | Si | 28.06 | 1430 |
| Silver | 47 | Ag | 107 880 | 960.5 |
| Sodium | 11 | Na | 22 997 | 97.7 |
| Strontium | 38 | Sr | 87.63 | 770 |
| Sulphur | 16 | S | 32 06 | 119.2 |
| Tantalum | 73 | Ta | 180 88 | 3000 |
| Tellurium | 52 | Te | 127 61 | 450 |
| Terbium | 65 | Tb | 159.2 | 327 |
| Thallium | 81 | Tl | 204 39 | 300 |
| Thorium | 90 | Th | 232 12 | 1700 |
| Thulium | 69 | Tm | 169.4 | |
| Tin | 50 | Sn | 118.70 | 231.9 |
| Titanium | 22 | Ti | 47 90 | 1820 |
| Tungsten | 74 | W | 184.0 | 3410 |
| Uranium | 92 | U | 238.14 | 1850 |
| Vanadium | 23 | V | 50.95 | 1735 |
| Virginium | 87 | Vi | | |
| Xenon | 54 | Xe | 131.3 | −112 |
| Ytterbium | 70 | Yb | 173.04 | 1500 |
| Yttrium | 39 | Y | 88.92 | 1490 |
| Zinc | 30 | Zn | 65.38 | 419.5 |
| Zirconium | 40 | Zr | 91.22 | 1700 |

From the National Bureau of Standards.

All above figures are the approved figures of the International Committee except those relating to Actinium, Masurium, Polonium, and Virginium, which have not yet been officially determined. Temperatures below −190 deg. C. are on the thermodynamic scale.

## The Electrochemical Series of Elements

In the table given below, the elements are electropositive to the ones which follow them, and will displace them from solutions of their salts

| | | |
|---|---|---|
| 1. Cesium | 23. Nickel | 45. Silicon |
| 2. Rubidium | 24. Cobalt | 46. Titanium |
| 3. Potassium | 25. Thallium | 47. Columbium |
| 4. Sodium | 26. Cadmium | 48. Tantalum |
| 5. Lithium | 27. Lead | 49. Tellurium |
| 6. Barium | 28. Germanium | 50. Antimony |
| 7. Strontium | 29. Indium | 51. Carbon |
| 8. Calcium | 30 Gallium | 52. Boron |
| 9. Magnesium | 31. Bismuth | 53. Tungsten |
| 10. Beryllium | 32. Uranium | 54. Molybdenum |
| 11. Ytterbium | 33. Copper | 55. Vanadium |
| 12. Erbium | 34. Silver | 56. Chromium |
| 13. Scandium | 35. Mercury | 57. Arsenic |
| 14. Aluminum | 36. Palladium | 58. Phosphorus |
| 15. Zirconium | 37. Ruthenium | 59. Selenium |
| 16. Thorium | 38. Rhodium | 60. Iodine |
| 17. Cerium | 39. Platinum | 61. Bromine |
| 18. Didymium | 40. Iridium | 62. Chlorine |
| 19. Lanthanum | 41. Osmium | 63. Fluorine |
| 20. Manganese | 42. Gold | 64. Nitrogen |
| 21. Zinc | 43. Hydrogen | 65. Sulphur |
| 22. Iron | 44. Tin | 66. Oxygen |

## Definitions Relating to Minerals

**Amorphous.** Without definite structure.

**Alluvium.** Fine material or sediment deposited by streams.

**Breccia.** Fragmental rock with angular components.

**Calcareous.** Containing sufficient calcium carbonate to effervesce visibly when treated with hydrochloric acid.

**Caliche.** Cemented deposits of calcium carbonate materials.

**Colloid.** Small particle size and high surface area per unit of mass. Colloid solutions are dispersed in particle state, not in molecular state like true solutions.

**Concretions.** Local concentrations of mineral compounds in other minerals.

**Detritus.** Heterogeneous mass of fragments of stone.

**Friable.** Easily crumbled in the fingers.

**Ferruginous.** Iron-bearing materials usually containing iron oxides.

**Igneous.** Rocks produced by the cooling of melted material.

**Marl.** Earthy crumbling deposit containing chiefly calcium carbonate and clay.

**Tufa.** A porous rock formed as a deposit from springs or streams.

**Tuff.** Rock composed of the finer kinds of volcanic detritus.

## Temperatures Available for Melting and Welding

| | |
|---|---|
| Direct electric arc | 4000°C. |
| Oxygen-acetylene torch | 3500°C. |
| Electric furnace | 3000°C. |
| Aluminum-iron oxide powder | 2800°C. |
| Combustion furnace | 1700°C. |
| Oxygen-hydrogen torch | 1450°C. |

## Reflecting Powers of Various Metal Surfaces

| | White light directly reflected, per cent | Color Silver = 0 |
|---|---|---|
| Silver | 90 | 0 |
| Chromium | 61 | Blue-green 12 units |
| Nickel | 50 | Red 16 units |
| Stainless steel | 49 | Blue-green 3 units |
| White bronze speculum | 70 | Red 1 unit |

## Color Designation

Fundamental color factors are Hue, Brightness, Saturation.

**Hue** is the predominant light-wave length reflected by the coloring material, and determines the Color designation.

**Brightness** is the percentage of light reflected. A brilliant white approaches 100 per cent, and a jet black approaches 0 per cent.

**Saturation** is the percentage of reflected light which is colored, and determines the Tint. A Color, or Hue, is tinted by its mixture with white.

**Black** is the absence of light waves; **White** is a combination of all the various wave lengths. White light is broken down by reflection into separate wave bands, or Hues.

## Thermal Conductivity of Materials[1]

Conductivity measured in British thermal units transmitted per hour per square foot of material 1 in. thick, per degree Fahrenheit difference in temperature of the two faces

| | | | |
|---|---|---|---|
| Silver | 2,920.0 | Diatomite block | 0.58 |
| Copper | 2,588 0 | Magnesia, 85 per cent | 0 51 |
| Steel, 1.0 carbon | 328.0 | Wood pulp board | 0.39 |
| Building stone | 12 50 | Bagasse board | 0.35 |
| Slate shingles | 10.37 | Cork, ground | 0.31 |
| Concrete, 1–2–4 | 6.10 | Flax fiber | 0 31 |
| Glass, plate | 5.53 | Diatomite powder | 0 308 |
| Brickwork, mortar bond | 4.00 | Mineral wool | 0.296 |
| Gypsum plaster | 2.32 | Asbestos sheet | 0.29 |
| Brick, dry | 1.21 | Vermiculite | 0.263 |
| Air space, 3½ in | 1.10 | Wool | 0.261 |
| Pine wood | 0.958 | Hair felt | 0.26 |
| Clay tile | 0 60 | Cotton, compressed | 0.206 |

[1] From Paul M. Tyler, U.S. Bureau of Mines.

## Electrical Conductivity of Elements Used in Alloys

| | | | |
|---|---|---|---|
| Silver | 100 00 | Iron | 14.57 |
| Copper | 97.61 | Platinum | 14 43 |
| Gold | 76.61 | Tin | 14.39 |
| Aluminum | 63.00 | Tungsten | 14.00 |
| Tantalum | 54.63 | Osmium | 13.98 |
| Magnesium | 39.44 | Titanium | 13.73 |
| Sodium | 31.98 | Iridium | 13.52 |
| Beryllium | 31.13 | Ruthenium | 13.22 |
| Barium | 30.61 | Nickel | 12.89 |
| Zinc | 29.57 | Rhodium | 12.60 |
| Indium | 26.98 | Palladium | 12.00 |
| Cadmium | 24.38 | Steel | 12.00 |
| Calcium | 21.77 | Thallium | 9.13 |
| Rubidium | 20.46 | Lead | 8.42 |
| Cesium | 20.00 | Columbium | 5.13 |
| Lithium | 18.68 | Vanadium | 4.95 |
| Molybdenum | 17.60 | Arsenic | 4.90 |
| Cobalt | 16.93 | Antimony | 3.59 |
| Uranium | 16.47 | Mercury | 1.75 |
| Chromium | 16.00 | Bismuth | 1.40 |
| Manganese | 15.75 | Tellurium | 0.001 |

## Melting Points of Materials Commonly Used for Heat-treating Baths

| Material | Melting points | |
|---|---|---|
| | Deg. F. | Deg. C. |
| 35 per cent lead, 65 per cent tin | 358 | 181 |
| 50 per cent sodium nitrate, 50 per cent potassium nitrate | 424 | 218 |
| Tin | 450 | 232 |
| Sodium nitrate | 586 | 308 |
| Lead | 620 | 327 |
| Potassium nitrate | 642 | 339 |
| 45 per cent sodium chloride, 55 per cent sodium sulphate | 1154 | 623 |
| Sodium chloride (common salt) | 1474 | 801 |
| Sodium sulphate | 1618 | 881 |
| Barium chloride | 1760 | 960 |

## Forging Temperatures of Steels

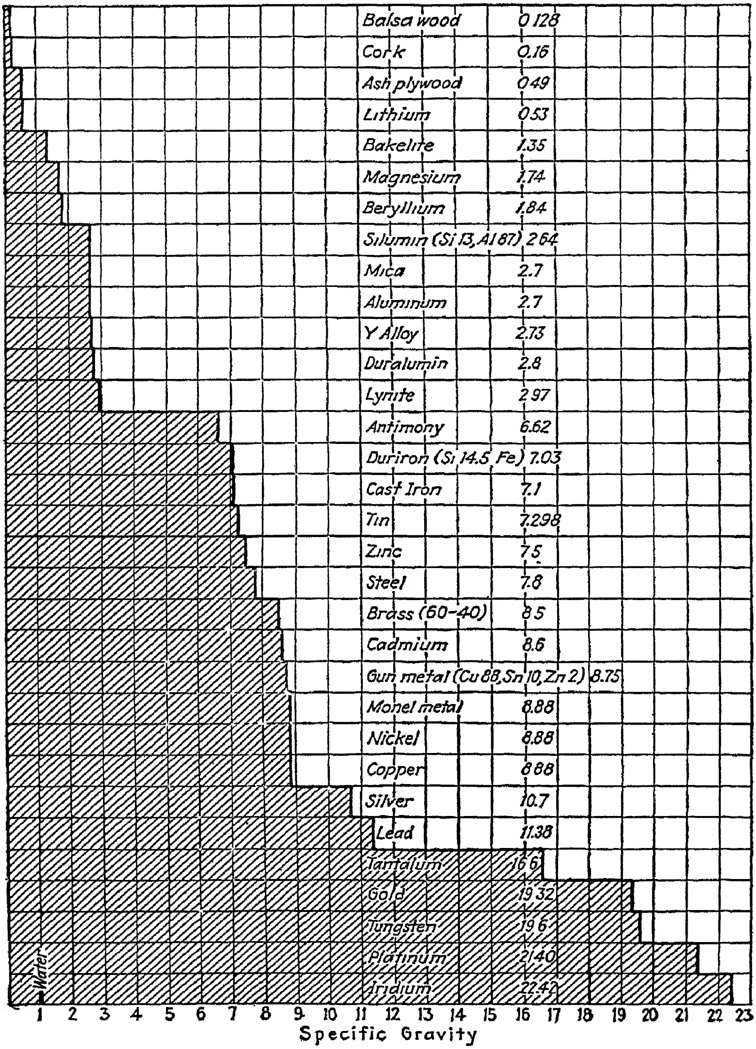
| | Maximum forging temperatures, deg. F. | Burning temperatures, deg. F. |
|---|---|---|
| 1.5 per cent Carbon steel | 1920 | 2080 |
| 1.1 per cent Carbon steel | 1980 | 2140 |
| 0.9 per cent Carbon steel | 2050 | 2230 |
| 0.7 per cent Carbon steel | 2140 | 2340 |
| 0.5 per cent Carbon steel | 2280 | 2460 |
| 0.2 per cent Carbon steel | 2410 | 2680 |
| 0.1 per cent Carbon steel | 2460 | 2710 |
| Silico-manganese spring steel | 2280 | 2460 |
| 3 per cent Nickel steel | 2280 | 2500 |
| 3 per cent Nickel-chromium steel | 2280 | 2500 |
| Air-hardening Ni-Cr steel | 2280 | 2500 |
| 5 per cent Nickel (casehardening) steel | 2320 | 2640 |
| Chromium-vanadium steel | 2280 | 2460 |
| High-speed steel | 2370 | 2520 |
| Stainless steel | 2340 | 2520 |
| Austenitic Chromium-nickel steel | 2370 | 2590 |

## Specific Gravities and Weights

For rough estimating of common construction materials

| | Specific gravity | Weight, pounds per cubic foot |
|---|---|---|
| Aluminum | 2.6 | 165 |
| Bronze | 8.0 | 509 |
| Cast iron | 7.2 | 450 |
| Copper | 8.9 | 556 |
| Glass | 2.5 | 160 |
| Lead | 11.37 | 710 |
| Nickel | 8 9 | 556 |
| Steel | 7.8 | 490 |
| Zinc | 7 0 | 440 |
| Ash, dry | 0.63 | 40 |
| Cedar, dry | 0.36 | 22 |
| Fir, dry | 0.56 | 32 |
| Maple, dry | 0 65 | 43 |
| Redwood, dry | 0.42 | 26 |
| White pine, dry | 0 41 | 26 |
| Granite | 2.6 | 165 |
| Limestone | 2.5 | 165 |
| Sandstone | 1.8 | 110 |
| Pressed brick | 2.2 | 140 |
| Common brick | 1.9 | 120 |
| Concrete | 2.3 | 144 |
| Portland cement | 3 0 | 183 |
| Mortar | 1.7 | 103 |
| Earth, dry, loose | ... | 76 |
| Earth, dry, packed | .. | 95 |
| Sand and gravel | . | 60 |

**Relative Weights of Materials**



## Average Percentage of Metals in Igneous Rocks

| Metal | Percentage | Metal | Percentage |
|---|---|---|---|
| Silicon | 27.72 | Rare earths | 0.015 |
| Aluminum | 8.13 | Copper | 0.010 |
| Iron | 5.01 | Tungsten | 0.005 |
| Calcium | 3.63 | Lithium | 0.004 |
| Sodium | 2.85 | Zinc | 0.004 |
| Potassium | 2.60 | Columbium, Tantalum | 0.003 |
| Titanium | 0.63 | Hafnium | 0.003 |
| Manganese | 0.10 | Thorium | 0.002 |
| Barium | 0.05 | Lead | 0.002 – |
| Chromium | 0.037 | Cobalt | 0.001 |
| Zirconium | 0.026 | Beryllium | 0.001 |
| Nickel | 0.020 | Strontium | 0.001 – |
| Vanadium | 0.017 | Uranium | 0.001 – |

## Occurrence of the Elements in the Earth's Crust[1]

| Element | Percentage | Element | Percentage |
|---|---|---|---|
| Oxygen | 47.0 | Carbon | 0.2 |
| Silicon | 28.0 | Phosphorus | 0.1 |
| Aluminum | 8.0 | Sulphur | 0.1 |
| Iron | 4.5 | Nickel | 0.02 |
| Calcium | 3.5 | Copper | 0.002 |
| Magnesium | 2.5 | Lead and Zinc | 0.0001 |
| Sodium | 2.5 | Tin | 0.00001 |
| Potassium | 2.5 | Silver | 0.000001 |
| Titanium | 0.4 | All others | 0.48 |
| Hydrogen | 0.2 | Total | 100.00 |

[1] Data from U.S. Geological Survey.

## Relative Amounts of Engineering Materials[1]

| | | | |
|---|---|---|---|
| Aluminum | 4,000 | Nickel | 10 |
| Iron | 2,200 | Copper | 1 |
| Magnesium | 1,200 | | |

[1] Data from U.S. Geological Survey.

### Composition of the Sea Water[1]

The average salt content of the sea is 3.5 per cent, with the salts divided as follows:

| | |
|---|---|
| NaCl | 77.76 per cent |
| $MaCl_2$ | 10.88 |
| $MgSO_4$ | 4.74 |
| $CaSO_4$ | 3.60 |
| $K_2SO_4$ | 2 46 |
| $MgBr_2$ | 0 22 |
| $CaCO_3$ | 0.34 |

In addition, sea water carries perceptible quantities of the following: Iodine, fluorine, arsenic, gold, silver, rubidium, copper, barium, phosphorus, manganese, lithium, lead, iron, strontium, and zinc. Ammonia is also usually present, together with free oxygen, nitrogen, and other gases, and in some seas hydrogen sulphide is also present. This does not include the mineral and organic materials carried in suspension by the water, especially near the mouths of great rivers.

### Composition of the Atmosphere[1]

| | | |
|---|---|---|
| Nitrogen | 78.03 | per cent (by volume) |
| Oxygen | 20.99 | |
| Argon | 0 94 | |
| Carbon dioxide | 0.03 | |
| Hydrogen | 0 01 | |
| Neon | 0.00123 | |
| Helium | 0 0004 | |
| Krypton | 0 00005 | |
| Xenon | 0.000006 | |

In addition, the atmosphere is always diluted with varying amounts of water vapor, dust, and smoke.

[1] U.S. Geological Survey.

# INDEX

B

D

L

U



V

W
2827